

lateral stress coefficient. This mechanism is difficult to quantify and has not been used for the analysis.

6.2.1 Subsurface Profile at SH 200

The subsurface profile for SH 200 was developed based on the geotechnical explorations conducted at the site by CH2M HILL and others (CH2M HILL, 2005; CH2M HILL, 2006b). Only the embankment and reservoir sediment layers are assumed to contribute drag load to the piles (CH2M HILL, 2006c). This evaluation is based on the assumption that the alluvium layer (which is a cohesionless, granular material) will undergo negligible settlement as a result of reservoir drawdown. As discussed in Section 6.2. SH 200 Abutment Evaluation, the estimated settlement for the alluvium is much less than 0.25-inch, and this settlement likely occurs at the neutral plane for the piles, contributing to no additional drag load.

The subsurface profile used to model pile load at each bent is summarized in Table 6-6. Cross sections at the abutments are also attached to this memorandum for more detail in Figures 7 and 8.

TABLE 6-6
Generalized Subsurface Profile—SH 200

Layer	Bent No. 1 (West Abutment)		Bent No. 2		Bent No. 5 (East Abutment)	
	Elevation (ft, NAVD 1988)	Depth (ft, bgs)	Elevation (ft, NAVD 1988)	Depth (ft, bgs)	Elevation (ft, NAVD 1988)	Depth (ft, bgs)
Embankment	3288	0	NA	NA	3290	0
Reservoir Sediments	3260	28	3257	0	3260	30
Alluvium	3248	40	3249	8	3250	40
Argillite	<3158	>130	<3158	>100	<3158	>130

Note: All elevations are based on the North American Vertical Datum, NAVD 1988.

Groundwater elevations at the bents are assumed to be approximately equivalent to the adjacent reservoir pool elevation. At full pool, the reservoir pool elevation is 3261.8 feet. The predicted end-of-stage 1, stage 2, and stage 3 drawdown elevations for SH 200 are summarized in Table 3-4. A schedule showing the timing of the predicted drawdown and river elevation (Envirocon, 2005) is also attached to this report (see Appendix E). In addition, a plot of the existing and predicted vertical effective stress is given for each abutment and attached to this report (see Appendix E). These plots indicate a relatively small change in effective stress in the zone of pile embedment.

6.2.2 Subsurface Properties

Properties of individual subsurface layers were evaluated separately. Soil parameters were selected for design based on evaluation of laboratory strength and index testing, and observations and tests conducted during the field exploration. These parameters are summarized in Table 6-7.

TABLE 6-7
Subsurface Properties

Layer	Unit Weight, γ_m (pcf)	Cohesion Intercept, c (psf)	Friction Angle, ϕ (Deg)
Embankment	120	0	35
Reservoir Sediment (effective stress)	90	0	31
Alluvium	120	0	35

6.2.3 Drag Loads

For the effective stress method, a key component in estimating β is the horizontal earth pressure, K_s . A ratio of K_s/K_o equal to 1.5 was selected for this analysis. This value is regarded by CH2M HILL as being high, but was selected for conservatism. The K_o values for the embankment and sediment layers were estimated to be 0.43 to 0.48, respectively. Using an interface friction between soil and timber (δ) equal to 0.8 times ϕ (Kulhawy, 1984), and the effective stress friction angles in Table 6-7, a β -value equal to 0.34 was computed $[(K_s/K_o)(K_o)\tan(\delta)]$ for the embankment and sediment layers. This value is regarded as conservative (i.e., results in higher drag load values), since the procedure given in the FHWA pile design manual (FHWA, 1996) results in a β -value of 0.30 (Fellenius, 1991).

Drag loads are being evaluated to determine the increase in drag caused by reservoir drawdown relative to the drag load that would be computed to exist before reservoir drawdown occurred. For this evaluation, drag loads on the existing timber piles were compared between the Stage 1 reservoir level and the Stage 3 reservoir level for SH 200. This change in drag load was evaluated first for individual piles and then for the pile group with consideration for the number and proximity of piles within each bent.

The drag load for individual piles was estimated on the basis of the side resistance along the piles computed using the beta values discussed above. As noted previously, the change in circumference was considered for this computation, but the potential effects of pile taper on pile side resistance were not considered. It was also assumed that the direction of shear also would not affect the magnitude of the side shear value.

Group drag load was evaluated by two methods, in accordance with FHWA guidelines (1996):

1. The sum of individual pile drag load times the number of piles times a group efficiency factor (see discussion below, under Ultimate Resistance Evaluation), or
2. The drag load of an "equivalent pier," which is the drag load on a pier defined as the size of the perimeter of the pile group. In the opinion of CH2M HILL, this method may overestimate the drag loads, but it was included to explain the possible range of values.

The drag load for each pile was then determined by dividing the group drag load by the number of piles in the group, under the premise that the group drag load would be spread uniformly between the piles in the group. This comparison found that the greatest drag load was for the equivalent pier case at each bent.

The estimated maximum range in drag load at the end of reservoir drawdown is summarized in Table 6-8. The corresponding change in drag load that results from this drawdown is summarized in Table 6-9.

TABLE 6-8
SH 200 Drag Load Summary

Pile (12" Timber Pile)	Estimated Drag Load for Stage 3 Water Surface (All Values in Kips)		
	Bent No. 1 (West Abutment)	Bent No. 2	Bent No. 5 (East Abutment)
Individual Pile	64 to 93	3 to 4	64 to 73
Pile Group	386 to 556	45 to 55	705 to 806

Note: Individual drag loads were computed for a timber pile with a taper of 0.8 percent, or 0.1 in/ft.

TABLE 6-9
SH 200 Change in Drag Load Summary

Pile (12" Timber Pile)	Estimated Change in Drag Load from Stage 1 to Stage 3 Water Surface (All Values in Kips)		
	Bent No. 1 (West Abutment) (6 Piles in Group)	Bent No. 2 (14 Piles in Group)	Bent No. 5 (East Abutment) (11 Piles in Group)
Individual Pile	<1	<1	<1
Pile Group	3 to 7	7 to 8	2 to 4

Note: Individual drag loads were computed for a timber pile with a taper of 0.8 percent, or 0.1 in/ft.

The change in drag load is most pronounced for Bent No. 2 because each group is so large. Each group at this bent consists of 14 piles, and the plan area of the group is approximately 9 feet by 9 feet. The effective stress change at this bent is also most significant, since the top of the pile is near the Stage 1 water surface and therefore a larger length of the pile feels the change in stress due to drawdown.

For Bent Nos. 1 and 5, the change in drag load resulting from reservoir drawdown is very small compared to the existing drag load on the piles. Based on the values given in Tables 6-8 and 6-9, drawdown of the reservoir results in a less than 2 percent increase in drag load for the piles at Bent Nos. 1 and 5, regardless of the methodology used to estimate individual and group drag load.

6.2.4 Ultimate Resistance Evaluation

The effective stress method was also used to estimate ultimate pile resistance. For evaluating toe resistance, R_t , the toe bearing coefficient, N_t , was selected based on the friction angle of the soil in which the pile was terminated. For the alluvium layer, the N_t is estimated to be equal to 60 (FHWA, 1996).

The resulting ultimate resistance (R_u) is equal to the shaft resistance (R_s) plus the toe resistance (R_t). For an individual pile, the ultimate resistance for Bent Nos. 1 and 5 (40-foot

timber piles) was estimated by assuming the full toe resistance contribution added to the shaft resistance contributed by all three layers. For Bent No. 2 (30-foot pile), no fill is present, so R_s is developed in the sediment and alluvium layers only. The estimated toe resistance, R_t , for Bent Nos. 1, 2, and 5 is 162, 82, and 173 kips, respectively.

Because of the configuration of the piles and spacing between piles, group effects were taken into account to determine the recommended ultimate resistance. For SH 200, a group efficiency factor was applied to the individual pile shaft resistance, only within the more cohesive reservoir sediments layer. For an average pile-to-pile spacing of 2.5 feet (s/D equal to 2.5 for a 12-inch timber pile), the group efficiency factor, η , is 0.65 (AASHTO, 2006 Interim). Within the cohesionless embankment layer and the alluvium layer, η was selected as 1.0, as recommended by AASHTO for cohesionless soil. The resulting estimated (unfactored) ultimate resistance for individual piles and for the pile group is summarized in Table 6-10.

TABLE 6-10
SH 200 Ultimate Resistance Summary

Pile (12" Timber Pile)	Estimated Ultimate Resistance, R_u (kips)		
	Bent No. 1 (West Abutment) (6 Piles in Group)	Bent No. 2 (14 Piles in Group)	Bent No. 5 (East Abutment) (11 Piles in Group)
Individual Pile	135	82	150
Pile Group	810	1,146	1,650

Note: Toe resistance of each pile, R_t , is limited by an σ^*N_t of 90,000 psf as per AASHTO recommendations.

6.2.5 Abutment Settlement

Settlement was estimated for the bridge abutments, using elastic compression for the alluvium and consolidation settlement for the reservoir sediments. For a water level fluctuation corresponding to the change from the normal pool (3261.8 feet) to the full drawdown (3242.1 feet), 0.9 inch of settlement was estimated. This estimate is regarded as conservative, since it includes approximately 0.3 inch of compression that would occur during each annual drawdown. No settlement was assumed to occur within the embankment layer (above the water elevation) as a result of drawdown.

The calculations also indicate that the additional elastic compression that will occur within the alluvium at the full drawdown level is much less than 0.25-inch.

6.2.6 Concluding Remarks on SH 200 Abutments

The drag load for individual piles listed in Table 6-8 should be used for evaluating the existing abutments and the factor of safety present on the current bridge abutment foundations. As summarized in Table 6-9, the change in drag load brought on by the lowering of the reservoir and groundwater table is very small, less than 2 percent of the existing estimated drag load on the piles. The reason for this small change in drag is because the zone of the existing pile that is within soil layers affected by the drawdown is very small at the abutments.

6.3 I90 Pier 3 and SH 200 Pier 3 Evaluation

The Draft Mitigation Report (CH2M HILL, 2005) recommended that the center pier for the I90 and SH 200 bridges be underpinned to mitigate for foundation scour post-drawdown. Because of the scour predicted at the existing bridge seals, the existing foundations are at risk for long-term instability, such as tipping or sliding. The footing seal for Pier 3 at the SH 200 bridge is founded in the alluvium; at the I90 bridges, the footing seals are keyed only very little into the surface of the argillite. The layout of each bridge and the location of Pier 3 is shown in Figure 1. Copies of the bridge as-built drawings, which illustrate the position of the pier footing and seal with respect to the subsurface layers are in Appendix E.

Drilled shafts were selected as the preferred alternative for underpinning at the piers, based on cost, constructability, and the desire to minimize impacts to traffic on the bridges. At SH 200, larger-diameter drilled shafts are recommended (diameter between 4 and 6 feet), to be advanced adjacent to the existing seal. For the I90 bridges, micropiles were originally proposed in the Draft Milltown Bridge Infrastructure Mitigation Report (CH2M HILL, 2005), because of the advantage of drilling a smaller-diameter element through the existing seal, and because of adaptability of drilling tools and equipment. After subsequent structural evaluation (and information collected about the integrity and dimensions of the existing seals) and conversations with drilled shaft contractors, small-diameter drilled shafts have been selected and evaluated instead (diameter between 1.5 and 2.5 feet).

The following portions of the report discuss the geotechnical related pier underpinning. Included are discussions of:

- Subsurface conditions, including recommended soil properties
- Shaft design parameters, including shaft diameter, length and axial resistance, uplift resistance, LRFD factors, lateral resistance, group effect, settlement, and constructability
- Axial Resistance
- Uplift Resistance
- Shaft Length and Diameter
- LRFD Recommended Resistance Factors
- Lateral Resistance Evaluation Input Parameters
- Group Effects Evaluation
- Minimum Shaft Lengths
- Construction Considerations

6.3.1 Subsurface Conditions at the Piers

Additional geotechnical exploration was performed in 2006, in order to supplement the subsurface information for the three bridge piers (CH2M HILL, 2005; CH2M HILL, 2006b). Cross sections illustrating the subsurface profile at each location are included in Figure 3. The subsurface profile at each pier was generalized for design and is summarized in Table 3-8.

TABLE 6-11
Geometry and Generalized Subsurface Profile

Layer	I90 Westbound Pier 3		I90 Eastbound Pier 3		SH 200 Pier 3	
	Elevation (ft, NAVD 1988)	Depth below top of existing seal (ft)	Elevation (ft, NAVD 1988)	Depth below top of existing seal (ft)	Elevation (ft, NAVD 1988)	Depth below head of shaft (ft)
Head of Shaft/Top of Existing Seal	3235	—	3238	—	3248	—
Bottom of Existing Seal	3223	12	3226	12	3229	—
Alluvium	3231	4	3231**	7	3226	22
Argillite Type I	3224	11	3227	11	—	—
Argillite Type II	3213	22	3212	26	~ 3150	~ 98*

Note: All elevations are based on the North American Vertical Datum, NAVD 1988

* Argillite at SH 200 was not classified into Type I and Type II rock

** Elevation interpolated from adjacent borings

6.3.1.2 Subsurface Properties

Properties of individual subsurface layers were selected during an earlier phase of the project. Parameters for design were determined based on evaluation of laboratory strength and index testing, and on observations and tests conducted during the field exploration. The design parameters are generally consistent with those used in the stability analysis of slopes and embankments, although these parameters may be revised as the design is finalized. The parameters used in evaluation of drilled shafts at the bridge piers are summarized in Table 6-12.

TABLE 6-12
Subsurface Properties

Layer	Unit Weight, γ_m (pcf)	Cohesion Intercept, c (psf)	End Bearing Coefficient, N_t	Friction Angle, ϕ (Deg)
Embankment	120	0	75	35
Reservoir Sediment (total stress)	90	145		18
Reservoir Sediment (effective stress)	90	0	30	31
Alluvium	120	0	40	35
Argillite	140	See Note		See Note

Note: Characteristics of the argillite were separated into Type I and Type II rock, in Section 3.2.4 Argillite Bedrock. See section for details.

Rock mass characteristics were evaluated separately for the argillite, based on core drilling observations of discontinuities and on laboratory testing. These properties were discussed

in detail in Section 3.2.8 Argillite Bedrock. The values used in the geotechnical evaluation of drilled shaft resistance at the I90 bridges are summarized in Table 6-13.

TABLE 6-13
Argillite Rock Mass Properties

Property	Value	
	Type 1 Argillite	Type 2 Argillite
RQD	Range: 0 – 60 percent	Range: 10 – 60 percent
	Average: 6 percent	Average: 22 percent
Unconfined compressive strength, q_u	146 – 730 psi	3,500 psi
Friction angle of rock mass	25 degrees	30 degrees
Cohesion of rock mass	2,000 psf	4,200 psf

6.3.1.3 Blackfoot River Water Surface Elevations

Water surface elevation at each of the bridge piers is either determined by the reservoir pool or river stage. At full pool, the reservoir pool elevation is 3261.8 feet. The predicted end-of-stage 1, stage 2, and stage 3 drawdown elevations for SH 200 and the I90 bridges are summarized in Table 3-4. These water surfaces were used in the evaluation of shafts at each bridge pier, depending on the different load case evaluated.

6.3.2 Shaft Design Parameters

Drilled shafts were evaluated for axial resistance in accordance with guidelines outlined in FHWA Drilled Shafts: Construction Procedures and Design Methods (FHWA, 1999), or Drilled Shaft Manual. Determination of axial capacity also referred to methods outlined in the NCHRP document *Rock-Socketed Shafts for Highway Structure Foundations* (Transportation Research Board [TRB], 2006), which provides current recommendations for evaluating shafts in rock or intermediate geomaterial (IGM).

6.3.2.1 I90 Bridge Piers

For the I90 piers, where drilled shafts will terminate in the argillite, side resistance was evaluated both for bearing in IGM and for bearing in rock. Based on unconfined compressive strength of intact rock alone, the Type II argillite would classify as rock according to the Drilled Shaft Manual. However, the rock was observed to be highly fractured with dipping bedding planes and closely spaced joint sets. Based on these rock mass characteristics, the Type II argillite is classified as a cohesive IGM. Classification as a cohesive IGM results in a more conservative resistance than does classifying the material as rock.

Base resistance was evaluated for a fractured rock mass, as per guidelines in the Drilled Shaft Manual. This procedure is relevant whether the geomaterial classification is cohesive IGM or rock, and is a function of unconfined compressive strength and characteristics of discontinuities within the rock mass.

6.3.2.2 SH 200 Bridge Pier

The estimate of axial compression capacity included side resistance and toe resistance, consistent with AASHTO specifications (AASHTO, 2006). Evaluation of the side resistance was based on effective stress " β " methods. Two methods were used to estimate the parameter β .

- 1) An empirical correlation with depth as presented in AASHTO LRFD Guidelines.
- 2) A theoretical calculation based on $\beta = K \cdot \tan \delta$. The value of K used in the calculation was taken to be equal to K_0 , though this is believed to be conservative for drilled shafts in coarse alluvium. The value of δ was assumed to be equal to the soil angle of internal friction ϕ .

Base resistance was evaluated in the alluvium using the properties in Table 6-12, in accordance with LRFD guidelines (AASHTO, 2006). This methodology regards the alluvium as a cohesionless, and evaluates toe resistance as a function of average blow count. Other methods considered include tip resistance as a function of N_t as recommended by FHWA (1996), and the methodology for bearing capacity outlined in the Drilled Shaft Manual (FHWA, 1999).

The LRFD (AASHTO, 2006) empirical method resulted in a more conservative estimate. Because of the uncertainty of drilled shafts in this material, and because this is the relevant design code, these values were included in this report.

6.3.2.3 Shaft Diameter, Length, and Axial Resistance—I90 Bridges

Drilled shafts for underpinning the I90 bridges are being designed to be constructed by drilling through the existing bridge seal, adjacent to the outside face of the overlying bridge footing. Because of the limited exposed area of the surface of the seal, small-diameter shafts were evaluated: 1.5 foot, 2.0 foot, and 2.5 foot.

Shaft lengths were evaluated for a range that is both practical for construction and that met the target axial capacity of each element. Predicted bridge scour for the 500-year event was also considered in selecting a minimum length for drilled shafts. As a result, shafts up to 40 feet in length were evaluated for the I90 underpinning.

Axial resistance was estimated for the AASHTO LRFD strength, service, and extreme limit states. Within the different load cases for each limit state, axial resistance was evaluated for the ground surface at the general scour elevation, and for the ground surface at the 500-year event scour elevation. The estimated axial resistance for the general scour condition, for each diameter, is summarized in Table 6-14.

TABLE 6-14
Axial Resistance Summary—General Scour Surface

Shaft Diameter	Estimated Ultimate Axial Resistance (kips)			
	I90 Westbound		I90 Eastbound	
	Side Resistance, Q_s	Side Resistance Plus Base Resistance, $Q_s + Q_t$	Side Resistance, Q_s	Side Resistance Plus Base Resistance, $Q_s + Q_t$
1.5-foot	1,285	1,379	1,103	1,197
2.0-foot	1,713	1,880	1,471	1,638
2.5-foot	2,142	2,402	1,839	2,099

Estimated axial capacities for the 500-year event scour surface are summarized in Table 6-15.

TABLE 6-15
Axial Resistance Summary—500-Year Scour Surface

Shaft Diameter	Estimated Ultimate Axial Resistance (kips)			
	I90 Westbound		I90 Eastbound	
	Side Resistance, Q_s	Side Resistance Plus Base Resistance, $Q_s + Q_t$	Side Resistance, Q_s	Side Resistance Plus Base Resistance, $Q_s + Q_t$
1.5-foot	1,162	1,255	955	1,049
2.0-foot	1,549	1,715	1,274	1,440
2.5-foot	1,936	2,196	1,592	1,852

Based on the Drilled Shaft Manual guidelines for shafts socketed into cohesive IGM, an average unit side resistance of 15.9 ksf was used in the evaluation of axial capacity. For shafts socketed into rock, the design code recommends conducting a loading test to determine the ductility of the rock, in order to confirm if it is prudent to design shaft capacity as the sum of side resistance and base resistance. This should be considered as a requirement for construction, and could be used to optimize the length of shafts at I90.

6.3.2.4 Uplift Resistance—I90 Bridges

Uplift resistance of drilled shafts was evaluated in accordance with FHWA guidelines (1999). For the properties of the rock mass, uplift resistance is equal to 0.7 times side resistance. Side resistance was provided in Tables 6-14 and 6-15.

However, the critical load case for uplift is a different subsurface condition than what was evaluated for axial resistance. Uplift was evaluated for the post-scour case where scour has already occurred to the elevation listed in Table 3.4-1, and then the river has backfilled the scour hole around the pier foundation up to an elevation of 3230.5. The upper 5 feet of side resistance was neglected for the backfilled material (alluvium). The resulting unfactored uplift resistances are summarized in Table 6-16.

TABLE 6-16
Uplift Resistance Summary at I90

Shaft Diameter	Estimated Ultimate Uplift Resistance (kips)			
	I90 Westbound		I90 Eastbound	
	Post-Scour	Q500 Scour	Post-Scour	Q500 Scour
1.5-foot	900	813	772	668
2.0-foot	1,199	1,084	1,030	892
2.5-foot	1,499	1,355	1,287	1,114

Note: Uplift resistance does not include the weight of the shaft.

6.3.2.5 Shaft Diameter, Length, and Axial Resistance—SH 200 Bridge

Shaft underpinning for the SH 200 bridge is being designed for the shafts to be installed on two sides of the existing bridge footing, in a group of three shafts on each side. A new cap would be constructed to connect the new shafts to the existing spread footing. Because of the configuration of the existing footing and seal at the pier, and because the bridge is founded entirely on alluvium, the proposed shaft diameter range is 4 to 6 feet.

Shaft lengths that met the target axial capacity for the predicted 500-year event bridge scour event were considered in selecting a minimum length for drilled shafts. As a result, shafts up to 100 feet in length were evaluated for the SH 200 underpinning. During the Q500 scour event, the remaining shaft embedment depth is approximately 75 feet into the alluvium (below the scoured surface). Shaft lengths of 50 feet and 75 feet were also evaluated (with respective Q500 embedment lengths of approximately 25 feet and 50 feet).

Similar to the evaluation for the I90 bridges, axial resistance was evaluated for the ground surface at the general scour elevation, and for the ground surface at the 500-year event scour elevation to model the different LRFD load cases. The estimated axial resistance for the general scour ground surface, and for the Q500 scour surface is summarized in Table 6-17.

TABLE 6-17
Axial Resistance Summary at SH 200

Shaft Diameter	Estimated Unfactored Axial Resistance (kips)					
	General Scour Surface (for 3 Shaft Lengths)			Q500 Scour Surface (for 3 Shaft Lengths)		
	50 ft	75 ft	100 ft	50 ft	75 ft	100 ft
4.0-foot	1,353	2,064	2,555	947	1,538	1,973
5.0-foot	1,884	2,790	3,418	1,365	2,126	2,685
6.0-foot	2,491	3,601	4,371	1,855	2,795	3,484

Axial capacities in Table 6-17 include both side resistance and base resistance values. CH2M HILL regards these values as conservative for a 100-foot shaft. Methods other than the LRFD method result in axial resistances that are up to 40 percent higher for the same length shaft. Research on predicted versus measured drilled shaft capacity in gravelly soils (Rollins et al., 1997; Harraz, et al, 2005) also suggested that currently adopted methods to predict shaft capacity are overly conservative. The values in Table 6-17 are presented as the estimated capacity based on the currently accepted guidelines in the LRFD code. Implementation of a loading test program as part of the construction contract could be used to optimize length prior to installation of all shafts.

6.3.2.6 Uplift Resistance—SH 200 Bridge

Uplift resistance of drilled shafts was evaluated in accordance with FHWA guidelines (1999). For cohesionless soil, uplift resistance is equal to 0.75 times side resistance. Recommended unfactored uplift resistance is summarized in Table 6-18.

TABLE 6-18
Uplift Resistance Summary at SH 200

Shaft Diameter	Estimated Unfactored Uplift Resistance (kips)					
	General Scour Surface (for 3 Shaft Lengths)			Q500 Scour Surface (for 3 Shaft Lengths)		
	50 ft	75 ft	100 ft	50 ft	75 ft	100 ft
4.0-foot	554	1,042	1,378	275	665	954
5.0-foot	692	1,302	1,722	344	831	1,192
6.0-foot	830	1,563	2,066	413	998	1,431

Note: Uplift resistance does not account for the weight of the shaft.

6.3.2.7 LRFD Resistance Factors

The recommended resistance factors for single drilled shafts in both rock and sand (Alluvium) is 0.50 for base resistance and 0.55 for side resistance. For uplift resistance in rock, the recommended resistance factor is 0.40. For uplift resistance in sand, the recommended resistance factor is 0.45. Resistance factors were determined in accordance with LRFD Bridge Design Specifications (AASHTO, 2006).

6.3.2.8 Lateral Resistance Evaluation Input Parameters

The drilled shaft foundations at the center piers will experience lateral loads from earth pressures, traffic, wind, ice, and seismic events. The pile and soil response to these loads can be modeled and evaluated using the program LPILE^{PLUS}, Version 4.0 for Windows (Ensoft, 2000). To assist in this evaluation, the recommended LPILE input parameters are provided in Table 6-19. These parameters were taken from the LPILE User's Manual for the following soil layers:

- Embankment material (model as *dense sand*)
- Reservoir Sediment (model as *soft clay with free water*)
 - Alluvium (model as *dense sand below water table*)
 - Type 1 Argillite (model as *weak rock*, according to the Reese model)
 - Type 2 Argillite (model as *weak rock*, according to the Reese model)

Groundwater was modeled at the top of the sediment (near normal operating pool).

TABLE 6-19
Recommended LPILE Input Parameters

Layer	γ_{total} (pcf)	S_u (psi)	ϕ (deg)	k (pci)	ϵ_{50} (dim)	E_r (psi)	q_u (psi)	RQD (%)	k_{rm} (dim)
Embankment	120	NA	35	90	NA	NA	NA	NA	NA
Reservoir Sediment	90	1.5	NA	20	0.02	NA	NA	NA	NA
Alluvium	120	NA	35	125	NA	NA	NA	NA	NA
Type 1 Argillite	140	NA	NA	NA	NA	4.7E4	500	6	0.0005
Type 2 Argillite	140	NA	NA	NA	NA	1.52E5	3500	22	0.0005

Notes:

γ_{total} = total unit weight

S_u = undrained shear strength

ϕ = internal friction angle

k = subgrade modulus

ϵ_{50} = strain at 50 percent of maximum stress

E_r = rock mass modulus

q_u = unconfined compressive strength

RQD = Rock Quality Designation

k_{rm} = weak rock strain parameter

6.3.2.9 Group Effects

Group effects for vertical and lateral loads were considered for the shafts at each bridge. Based on current layout and design diameter/spacing, no detrimental group effects are applied to shaft resistance at any of the bridges, in accordance with AASHTO LRFD guidelines (2006).

For lateral loads, the group effects should be considered if the spacing in the line of loading is less than 5 equivalent diameters, following recommendations in the AASHTO LRFD Bridge Design Specifications.

6.3.2.10 Estimated Minimum Shaft Lengths

Estimated minimum shaft lengths are controlled by uplift resistance at all three bridge piers. In addition to this requirement, a minimum penetration of 10 feet into the Type II argillite is recommended for the I90 structures. The recommended minimum shaft lengths are summarized in Table 6-20.

TABLE 6-20
Estimated Minimum Tip and Shaft Lengths

Layer	I90 Westbound Pier 3		I90 Eastbound Pier 3		SH 200 Pier 3*	
	Toe Elevation (ft, NAVD 1988)	Length (ft, bgs)	Toe Elevation (ft, NAVD 1988)	Length (ft, bgs)	Toe Elevation (ft, NAVD 1988)	Length (ft, bgs)
1.5-foot	3195	40	3198	40	—	
2.0-foot	3195	40	3198	40	—	
2.5-foot	3195	40	3198	40	—	
4.0-foot		—			3148	100
5.0-foot		—			3148	100
6.0-foot		—			3148	100

Note: All elevations are based on the North American Vertical Datum, NAVD 1988

* Estimated minimum lengths at the SH 200 bridge pier are given for a 5-foot diameter shaft.

6.3.2.11 Pier Settlement

Settlement of shafts is not anticipated to be significant. Within the rock layer, sufficient conservatism was incorporated into the axial resistance evaluation that settlement is anticipated to be negligible at the I90 piers. Although a detailed evaluation of settlement was not performed, elastic compression within the alluvium layer at the SH 200 pier is anticipated to be less than 1 inch for the methodology used to evaluate axial resistance. As shaft diameter and length is optimized during the final design of the underpinning, settlement should be evaluated.

6.3.2.12 Constructability

Construction of drilled shafts for the underpinning of all three bridges will need to consider several issues: working in flowing water with limited overhead clearance, drilling through hard and fractured or porous geomaterial with high surrounding water pressure, installing shafts with tight alignment and tolerance requirements because of the existing footings and seals, and achieving hole side and base conditions that are sufficient for achieving design values for resistance. It is recommended that a qualified geotechnical engineer be involved with reviewing contractor qualifications and submittals, and in providing construction observations to confirm design assumptions.

Drilled shafts at the I90 piers were evaluated assuming a smooth wall of the shaft within the argillite layer. It may be possible to reduce the required embedment or increase resistance by grooving the shaft sidewalls. At both I90 and SH 200, utilizing the proper slurry mix will be critical for maintaining hole diameter in highly fractured rock or in alluvium prone to sloughing. In addition, the contractor should utilize active measures to prevent concrete segregation within the shaft, especially under conditions with any shallow subsurface current due to river flows. Cross-hole sonic log (CSL) testing should be employed during the construction phase to ensure the final quality of installed shafts meets design assumptions.

Steel casing will be required both for installation of shafts and for final construction. This is especially important at SH 200 because the existing foundation is a spread footing on granular material and construction of an uncased shaft would likely undermine the foundation. Design of the shafts is underway at the time of this report writing, but it is anticipated that permanent steel casing will extend from the head of the shaft down to a point of minimum embedment within either the argillite or alluvium layer, depending on location. Permanent casing extending a few feet into the argillite was conservatively estimated to reduce axial resistance by 5 to 10 percent. Within the alluvium, contribution to side resistance was neglected in the upper 5 to 10 feet. If permanent casing extends below this point, axial resistance should be reevaluated.

For optimizing shaft length and proving out unit resistances in both highly fractured rock and in coarse gravel, loading tests are recommended. To be economically possible, loading tests should be incorporated into production shafts, either through segmental testing or by incorporating load cells in a sacrificial zone beneath the required shaft toe. Post-grouting the toe of installed shafts is another potential method to increase the reliability that design resistances are achieved in construction.

7.0 References

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Appendix A
Boring Logs

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C01

PAGE 1 of 3

DATE STARTED / FINISHED: 7/18/05 - 7/18/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3290.6 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17043672.1, 918748

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
							This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.						
							Pavement.						
		1					Moist, Brown [10YR 4/3], GRAVEL with Silt and Sand, GW-GM, non-plastic, very dense.						
		2											
		3				2" SS	61			100			
		4											Advanced 3.5-5.0' through gravel driller said was quite dense.
		5											Cuttings show rounded to angular gravels up to 3 in. diameter @ approx. 4-6'.
		6				2" SS	67		NP	NP 74		1.76	Advanced 6.5-10'. Driller stated very dense gravel.
		7											
		8											
		9											
		10											
		11				2" SS	61			39			Advanced 11.5-15' through gravels and sands. Driller says very dense gravel.
		12											
		13											
		14											
		15											
		16				2" SS	67		NP	NP 26			Advanced auger 16.5-20' through a very dense matrix of gravel and sand.
		17											
		18											
		19											Driller reports easier at 19'.
		20											
		21				2" SS	56		NP	NP 13			
							Moist, Brown [7.5YR 4/2], SAND with Silt and Gravel, SW-SM, non-plastic, medium dense.						



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PHONE NUMBER: 406-522-0251

DRILL HOLE LOG: MILLTOWN DAM.GPJ, PIEDMONT.GDT, 11/1/05

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
						2" SS	56	Moist, Brown [7.5YR 4/2], SAND with Silt and Gravel, SW-SM, non-plastic, medium dense. (Continued)	NP	NP	13			Advanced auger 21.5-25' through medium dense matrix of sand and gravel.
		22												
		23												
		24												
		25												
		26				2" SS	67	Moist, Dark olive brown [2.5Y 3/3], GRAVEL with Silt and Sand, GW-GM, non-plastic, medium dense.	NP	NP	20			Driller says harder drilling at 25'. Advanced 26.5-30'.
		27												
		28												
		29												
		30												
		31				2" SS	50	Saturated, Dark gray [2.5Y 4/1], ORGANIC SANDY SILT, OL, non-plastic, loose.			8			Encountered water table between 30' and 31' while drilling.
		32				2" SS	17	Saturated, Dark grayish brown [2.5Y 4/2], ORGANIC SANDY SILT, OL, low to medium plasticity, very stiff, wood debris present.			29			
		33												
		34				3" SS	72	Saturated, Dark brown [10YR 3/3], SILTY SAND with Gravel, SM, non-plastic, loose.	NP	NP	6			Advanced 34.5-35'. Broken rock clogged in sampler resulting in poor recovery @ 35'.
		35												
		36				2" SS	17	Saturated, Dark brown [10YR 3/3], SAND with Silt and Gravel, SP-SM, rounded, non-plastic, medium dense.			14			Advanced 36.5-40'. Driller indicates soft material 36-37.5' and then becomes slightly denser gravels.
		37												
		38												
		39												
		40												
		41				2" SS	17	Saturated, Brown [10YR 5/3], GRAVEL with Sand, GP, angular to subrounded, non-plastic, medium dense.			16			Fractured gravels from sampler. Fines on some rounded gravels but with poor recovery it is difficult to know the quantity of fines. Advanced 41.5-45'. Driller feels sandy gravels.
		42												
		43												
		44												



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45				61	Saturated, Light brown [7.5YR 6/3], GRAVEL with Sand, GP, angular to subrounded, non-plastic, dense, sands are medium to coarse grained.	NP	NP	36			Water measured at 44.07' on 8/26/05 in piezometer B.
		46				2" SS							Advanced 46.5-50'. Driller feels softer layers at start and end of advancing with denser gravels in the middle.
		47											
		48											
		49											
		50				67	Saturated, GRAVEL with Sand, GP, non-plastic, medium dense.	NP	NP	29			Advanced 51.5-55'. Driller feels gravels while advancing.
		51				2" SS							
		52											
		53											
		54											
		55				39	Saturated, Brown [10YR 4/3], GRAVEL with Sand, GP, subangular to rounded, non-plastic, medium dense.			30			Gravels fractured from split spoon.
		56				2" SS							Advanced 56.5-60' through gravels.
		57											
		58											
		59											
		60				33	Saturated, Light brownish gray [2.5Y 6/2], GRAVEL with Sand, GP, subangular to subrounded, non-plastic, very dense.			100			60 blows at 3" for interval 60.5-61'.
		61				2" SS							Advanced 61.5-65' through gravels.
		62											
		63											
		64											Driller feels material change at 64.5'. No recovery. Trying another split spoon to attempt to recover some weathered bedrock. Driller feels we are in bedrock-100 blows advances 1" recovered fractured bedrock
		65				100	Gray [2.5Y 6/1], GRAVEL with Clay and Sand, GP-GC, angular to subrounded, low to medium plasticity, very dense, suspect weathered argillaceous bedrock.			100			
		66					Total Depth 65'.						
		67											



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C02

PAGE 1 of 3

DATE STARTED / FINISHED: 7/17/05 - 7/17/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3279.5 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17043173.9, 919275.2

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
							Pavement 7 inches thick.						
		1					Moist, Dark reddish brown [5YR 3/2], GRAVEL with Silt and Sand, GW-GM, non-plastic, very dense, sands are medium grained.						
		2											Top of interval has what appears to be oil.
		3				2" SS	83			82			
		4											Advanced 3.5-4.5' in gravels.
		5				2" SS	67						
		6					Moist, Light brownish gray [10YR 6/2], GRAVEL with Sand, GW, non-plastic, dense,	NP	NP	33			Advanced 6-9.5' and material was less dense than EM-C03 EM-C04 and EM-C05 according to driller. Up to 3" diameter material visible in cuttings.
		7											
		8											
		9											
		10				2" SS	0			16			Probably pushed a rock. No rock stuck in bit of sampler.
		11					Medium dense, no recovery.						Advanced 11-14.5'. Probably gravels.
		12											
		13											
		14											
		15				2" SS	39			10			
		16					Moist, Brown [7.5YR 4/2], GRAVEL with Sand, GW, subrounded, non-plastic, loose.						Advanced 16-19.5'.
		17											
		18											
		19											
		20				2" SS	67			20			
		21					Moist, Grayish brown [10YR 5/2], SAND with Gravel, SP, non-plastic, medium dense, medium- to coarse-grained sand.	NP	NP				

This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.

REMARKS / TESTING



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		SAMPLE ID	RECOVERY (%)	This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED									
							MATERIAL DESCRIPTION						
		22					Moist, Grayish brown [10YR 5/2], SAND with Gravel, SP, non-plastic, medium dense, medium- to coarse-grained sand. (Continued)						Advanced 21-24.5'. Driller noted gravel while advancing.
		23											
		24											
		25			2" SS	61	Moist, Grayish brown [10YR 5/2], GRAVEL with Silt and Sand, GW-GM, subrounded, non-plastic, very dense.			78			Split spoon broke multiple rocks.
		26											Advanced 26-29.5' through gravels.
		27											Probably transitioned from fill to native material between 26-29'.
		28											Encountered groundwater while drilling at about 30'.
		29											
		30			2" SS	67	Saturated, Reddish brown [5YR 4/3], GRAVEL with Silt and Sand, GW-GM, subrounded, non-plastic, medium dense, fine- to coarse-grained sand.			30			Water measured at 31.7' on 8/26/05 in Piezometer A and at 31.1' in Piezometer B.
		31											
		32											
		33											
		34											
		35			2" SS	100	Saturated, Dark grayish brown [10Y 4/2], SAND with Gravel, SP, non-plastic, medium dense.	NP	NP	23			Advanced 36-39.5'.
		36											
		37											
		38											
		39											
		40			3" SS	67	Saturated, Dark grayish brown [10Y 4/2], SAND with Silt, SP-SM, non-plastic, medium dense, medium-grained sand.	NP	NP	12			Advanced 41-44.5' through sands.
		41											
		42											
		43											
		44											



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45	X			3" SS 100	Saturated, Brown [10YR 5/3], SAND with Silt and Gravel, SP-SM, non-plastic, very dense.			77			Rock fractured and clogged in top of sampler.
		46											Advanced 46-49.5'. Driller feels sands at 47'.
		47											
		48											
		49											
		50	X			2" SS 28	Saturated, Grayish brown [10YR 5/2], SAND, SP, medium dense.	NP	NP	13			0 blows from slough.
		51	X										Advanced 51-54.5'.
		52											
		53											
		54	X			2" SS 100	Saturated, Dark greenish gray [5GY 4/1], CLAYEY GRAVEL with Sand, GC, subrounded, low plasticity, very dense, suspect weathered argillaceous bedrock.			99			Driller feels material change at 54'.
		55					Total Depth 55'.						
		56											
		57											
		58											
		59											
		60											
		61											
		62											
		63											
		64											
		65											
		66											
		67											



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PHONE NUMBER: 406-522-0251

BOREHOLE LOCATION: 17042950.6, 919597.4

HAMMER TYPE: 140# Automatic Trip Hammer

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PHONE NUMBER: 406-522-0251

DRILL HOLE LOG MILLTOWN DAM.GPJ PIEDMONT.GDT 11/1/05

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
		22				Shelby	100	Saturated, Dark grayish brown [10YR 4/2], GRAVEL with Sand, GW, non-plastic, loose, no sands recovered. (Continued)						Advanced 21-24.5'.
		23						Saturated, Greenish gray [5GY 6/1], SAND with Silt, SP-SM, non-plastic, medium dense.						Driller reports "soft" material at 23'.
		24												Pocket penetrometer = 0.8 tsf
		25												
		26				Shelby	100		NP	NP			33.3	
		27				3" SS	67	Saturated, Very dark gray [10YR 3/1], SAND, SP, non-plastic, very loose, fine grained sand.			2			
		28												
		29				Shelby	92	Saturated, Black [2.5Y 2.5/1], SAND with Silt, SP-SM, non-plastic, very loose, fine to very fine grained sand, minor organics present.						Organics at bottom of Shelby tube sample.
		30												
		31				3" SS	100	Olive gray [5Y 4/2], SAND, SP, non-plastic, loose, fine to medium grained sand.			6			
		32						Saturated, SILT, ML, medium plasticity, firm, cohesive.						Water measured at 31.2' on 8/26/05 in Piezometer B.
		33				Shelby	100	Saturated, SAND with Silt, SP-SM, non-plastic, loose,						
		34												
		35				3" SS	0	Loose, no recovery, fine sand on bit (33.5' interval).			4			
		36				3" SS	89	Saturated, Very dark grayish brown [10YR 3/2], SAND, SP, non-plastic, very loose, fine-grained w/ woody organics.			4			Used catcher and brass liners.
		37						Saturated, Gray [N5], ELASTIC SILT, MH, high plasticity, firm, High plasticity gray clay from ~35.5'-36.25'.						
		38				2" SS	94	Saturated, Very dark grayish brown [2.5Y 3/2] Olive gray [5Y 4/2], SAND with Silt, SP-SM, loose, sand is fine to very fine grained w/ woody debris, silt at bottom of interval. (2nd color refers to lower 6")			6			
		39				Shelby	100	Saturated, Very dark gray [5Y 3/1], SILT with Sand, ML, firm, sand is very fine grained.	35	29		75.1	43.1	
		40						Saturated, Olive gray [5Y 4/2], SANDY SILT, ML, sand is fine to very fine grained.						40": torvane = 0.42 tsf ; 3 pocket penetrometer readings (no adapter) = 1.7 tsf 1.8 tsf 1.4 tsf
		41				3" SS	94	Saturated, SAND with Silt, SP-SM, low plasticity, loose, fine grained sand.			7			40.5": torvane = 0.35 tsf; 3 pocket pen readings = 1.0 tsf 1.1 tsf 7.1 tsf
		42				Shelby	42	Saturated, SILT, ML, medium plasticity, firm.						Pushed Shelby from 41.5' to 42.5'; stopped because very stiff.
		43						Saturated, SAND with Silt, SP-SM, low plasticity, loose.						
		44				2" SS	78	Saturated, SAND with Silt, SP-SM, low plasticity, dense, gravel at bottom of interval.			39			



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
							This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.						
		45	X			2" SS 50	Saturated, Olive gray [5Y 4/2], SAND with Gravel, SP, very dense, sand is coarse grained.			100			Advanced 44-44.5' to start 5-ft interval sampling.
		46											
		47											Advanced 46-49.5'. Grinding boulders while advancing to 47'. 47': Driller noted gravels present but drilling easier.
		48											
		49											
		50	X			3" SS 12	SAND with Silt and Gravel, SP-SM, subrounded, dense, sand is coarse to medium grained with fine gravels.			37			49.5': Top 14" SPT Test movement continuous. Probably a rock @ 14-16.75'. Advanced 51-54.5'. Driller stated gravels and not very difficult to advance. Similar to 46-49.5'.
		51											
		52											
		53											
		54											
		55	X			2" SS 50	Saturated, Grayish brown [2.5Y 5/2], GRAVEL with Sand, GW, rounded, non-plastic, medium dense.	NP	NP	21			55': Low blow count on first 6 inches due to slough. Advance 56-59.5'.
		56											
		57											
		58											
		59											
		60	X			3" SS 67	Saturated, Grayish brown [2.5Y 5/2], GRAVEL with Silt and Sand, GW-GM, non-plastic, medium dense.	NP	NP	27			
		61											
		62											
		63					Dry, Light gray [10YR 7/1] Light greenish gray [5GB 7/1], SAND with Silt and Gravel, SW-SM, very dense, material reduced to coarse and fine grained, grain size may be partially due to sampling method, secondary color for last 6", sample probably crushed, fractured, and weathered argillite bedrock.						Driller feels bedrock @ 62'.
		64											
		65	X			2" SS 38				100			
		66					Total Depth = 65.5'.						
		67											



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Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C04

PAGE 1 of 3

DATE STARTED / FINISHED: 7/15/05 - 7/16/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3285.0 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17042763.1, 919878.4

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		1					Moist, Brown [7.5YR 4/2], GRAVEL with Silt and Sand, GW-GM, subangular to rounded, non-plastic, very dense, sands are predominantly medium grained.						Sampled cuttings.
		2											
		3				2" SS	100			100			Advanced 3.5-4.5'.
		4											
		5				2" SS	56			75			Advanced 6-9.5'. Driller noted dense gravels with cobbles while advancing.
		6											
		7											
		8											
		9											
		10				2" SS	100			100			Split spoon bounced on rock. Cuttings taken from 9-11' as bulk sample.
		11						18	13				Driller noted dense gravel while advancing 11-14.5'.
		12											
		13											
		14											
		15				2" SS	80			100			Advanced 16-19.5'.
		16											
		17											
		18											
		19											
		20				2" SS	50			17			
		21					Moist, Light brown [7.5YR 6/3], GRAVEL with Sand, GW, non-plastic, medium dense.	NPNP					

This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.



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PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
							This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.						
		22					Moist, Light brown [7.5YR 6/3], GRAVEL with Sand, GW, non-plastic, medium dense. (Continued)						Advanced 21-24.5'. Driller noted cobbles while advancing.
		23											
		24											Encountered water while advancing at 24'.
		25				2" SS 50	Saturated, Brown [7.5YR 4/2], GRAVEL with Silt and Sand, GW-GM, subangular to subrounded, non-plastic, loose.			8			Water measured at 24.8' on 8/26/05 in Piezometer A.
		26				3" SS 100	Saturated, Olive gray [5Y 4/2] Dark brown [7.5YR 3/2], SILT with Sand, ML, no to low plasticity, very loose, sand is fine to very fine, sandy silt in upper 6" is firm, trace fibrous organic matter (old stems).			3			Organics present at 25.5'.
		27											
		28				2" SS 100	Saturated, Very dark gray [2.5Y 3/1], SILTY SAND, SM, low plasticity, loose, with a thin 2" lense of sandy low plasticity silt, ML, organics present, @ 28' varved in 1/8" thick layers alternating light to dark gray, non-plastic all layers.			5			
		29					Saturated, Dark gray [N4], SAND with Silt, SP-SM, fine grained sand.						Most likely ML layer in 29-31' interval. Plastic silt present on outside of shelby tube.
		30				Shelby 100	Saturated, Dark gray [N4], SILT, MH.	52	31				
		31											
		32				2" SS 56	Saturated, Dark gray [N4], SAND, SP, non-plastic, very loose, fine grained #20 to #40 weathers to reddish brown when oxidized.			1			
		33				3" SS 83	Saturated, SILT, ML, low plasticity, firm.						33': torvane = 0.3 tsf; Pocket penetrometer = 0.75 tsf 0.6 tsf 0.6 tsf.
		34					Saturated, Very dark gray [10YR 3/1] Dark gray [N4], SAND, SP, non-plastic, loose, fine to medium grained sand in upper 1', fine-grained in lower 1.5', contains thin lense of low plasticity clay about 1/2" thick, high plasticity silt in very top of sample.			5			
		35				2" SS 89				6			Water measured at 34.5' on 8/26/05 in Piezometer B.
		36				3" SS 83	Saturated, Very dark gray [10YR 3/1], ORGANIC SILT with SAND, OL, no to low plasticity, soft, fine grained to very fine grained sand, considerable organics in 36.5-37" brass liner.			3			
		37					Saturated, Dark grayish brown [2.5Y 4/2], SAND, SP, non-plastic, loose, fine grained sand.			5			
		38				2" SS 28							
		39				Shelby 83	Saturated, Olive gray [5Y 4/2], ELASTIC SILT, MH, medium plasticity, firm.	57	32		81.3	39.2	38.5': Bottom of SS had silt so decided to push a shelby tube.
		40					Saturated, Olive gray [5Y 4/2], SAND, SP, non-plastic, loose, fine grained sand.						
		41				2" SS 100	Saturated, Dark olive gray [5Y 3/2], SILTY SAND, SM, non-plastic, loose, fine to very fine grained sand, trace fine dark brown amorphous organics, varved in 1/8" thick layers w/ abundant organic matter @ 41.5-42'.			8			
		42					Saturated, Dark gray [5Y 4/1], SANDY SILT, ML, low plasticity, firm, varved with 1/8" thick laminae and some varves are medium plasticity clays.			8			42': Pocket penetrometer = 0.75 tsf 0.9 tsf 0.8 tsf.
		43				2" SS 100							
		44				3" SS 72	Saturated, Olive gray [5Y 4/2], SILTY SAND, SM, non-plastic, loose, fine to very fine grained, contains sticks to about 1/4 to 1/2" diameter, appears to be			5			



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
							This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.						
							intermixed with thin organic layers.						
		45	X			72	Saturated, Light gray [2.5Y 7/1], CLAY, CH, high plasticity, firm.	61	27	5	70.4	50.3	10-inch push before 'hard' gravels @ 46'.
		46				100	Saturated, Olive gray [5Y 4/2], GRAVEL with Sand, GP, non-plastic, very dense.						Started @ 46' on 7/16/05.
		47											Start advancing to 49.5' on 7/16/05. Driller noted tight gravels while advancing.
		48											
		49											
		50	X			100		NPNP	92				
		51											
		52											
		53											
		54											
		55	X			33	Saturated, Olive gray [5Y 4/2], GRAVEL with Sand, GP, rounded, medium dense.	NPNP	19				Advancing 56-59.5'.
		56											
		57											
		58											
		59	X			100	Saturated, Greenish gray [5GY 6/1], SILTY SAND with Gravel, SM, low to medium plasticity, very dense, gravels fine and angular, suspect weathered argillaceous bedrock.			86			Driller feels change in material at 59'.
		60					Total Depth 60'.						
		61											
		62											
		63											
		64											
		65											
		66											
		67											



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C05

PAGE 1 of 3

DATE STARTED / FINISHED: 7/16/05 - 7/17/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3292.4 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17042437.9, 920357.6

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED BULK								
						Pavement.						
		1				Moist, Brown [10YR 5/3], GRAVEL with Silt and Sand, GW-GM, subangular to rounded, non-plastic, very dense.						
		2	X		2" SS	50			100			Advanced 3.5-4.5'.
		3										
		4										
		5	X		2" SS	67		NP	NP 83			Advanced 6-9.5'. Driller noted tight gravels and cobbles while advancing.
		6										
		7										
		8										
		9										
		10	X		2" SS	100			100			Advanced 10-14.5'.
		11				Moist, Pale brown [10YR 6/3], GRAVEL with Silt and Sand, GW-GM, subangular to subrounded, non-plastic, very dense.						Driller noted boulder at approx. 12'. Driller didn't feel gravels from 13-15'.
		12										
		13										
		14										
		15	X		2" SS	72		NP	NP 54			Advanced 16-19.5'.
		16				Moist, Light brownish gray [10YR 6/2], GRAVEL with Silt and Sand, GW-GM, non-plastic, very dense.						
		17										
		18										
		19										
		20	X		2" SS	11			42			Rock clogged sampler.
		21										



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DRILL HOLE LOG: MILLTOWN DAM.GPJ, PIEDMONT.GDT 11/1/05

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22					Wet, Brown [10YR 5/3], GRAVEL with Silt and Sand, GW-GM, non-plastic, dense,						Advanced 21-24.5'. Driller noted gravels while advancing.
		23											
		24				0	Very dense, no recovery- split spoon bounced on rock. (Continued)			100			Driller feels large boulder 24.5-28'. Very slow advancing.
		25											
		26											
		27											
		28											
		29											
		30				50	Moist, Very pale brown [10YR 7/3], GRAVEL with Silt and Sand, GW-GM, non-plastic, very dense.			100			Material type appears to change from fill gravel to native gravels (30-34').
		31											
		32											Driller feels change at approximately 32'. Possibly ground water.
		33											
		34											
		35				47	Saturated, Light brownish gray [10YR 6/2], GRAVEL with Silt and Sand, GW-GM, no to low plasticity, very dense.	NP	16	100			Sample taken from below ground water table.
		36											Only enough sample for a plastic limit. Advanced to 37'.
		37											Start at 37' on 7/17/05. Advanced to 39.5'.
		38											
		39											Piezometer A dry at 38.7' on 8/26/05.
		40					Saturated, Grayish brown [10YR 5/2], GRAVEL with Silt and Sand, GP-GM, non-plastic, very dense.	NP	NP	51			A few 1.5-2" rocks fractured by the split spoon.
		41											Advanced 41-44.5'. Water measured at 41.2' on 8/26/05 in piezometer B.
		42					Saturated, Grayish brown [10YR 5/2], SAND, SP, non-plastic, medium dense.						Driller feels material change at 42'. Softer.
		43											
		44											



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45	X			61	Saturated, Grayish brown [10YR 5/2], SAND, SP, non-plastic, medium dense. (Continued)	NP	NP	26			High blow counts may be from breaking rock.
		46	X			33	Saturated, Grayish brown [10YR 5/2], GRAVEL with Silt and Sand, GP-GM, non-plastic, medium dense.	NP	NP				Blow counts from slough. Not using water right now so some material coming in through auger joints.
		47	X			33	Saturated, Yellowish brown [10YR 5/4], SAND with Silt and Gravel, SP-SM, non-plastic, loose.			9			Start using water @ 47.5'.
		48	X			33	Saturated, Light brownish gray [10YR 6/2], GRAVEL with Sand, GW, rounded, non-plastic, medium dense.			23			Material starting at 42' appears to be variable with sands and gravels to 47.5'.
		49	X			28	Saturated, Light brownish gray [10YR 6/2], SAND with Silt and Gravel, SP-SM, rounded, non-plastic, medium dense, sands are medium grained.	NP	NP	25			Advanced 49-49.5'.
		50	X										Advanced 51-54.5'. Driller noted gravels while advancing.
		51	X										
		52	X										
		53	X										
		54	X										
		55	X			17	Saturated, Light brownish gray [10YR 6/2], SAND with Gravel, SP, rounded, non-plastic, dense, sands are medium grained.			31			Advanced 56-59.5'.
		56	X			80	Light gray [2.5Y 7/1], medium plasticity, very dense, bedrock is weathered and fractured by split spoon into sand-size and smaller particles, the smaller of which are medium plasticity.			92			Driller notices a change in material at 57' (more dense). Stopped advancing at 57' to collect sample.
		57	X				Total Depth 57.5'.						
		58											
		59											
		60											
		61											
		62											
		63											
		64											
		65											
		66											
		67											



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C06

PAGE 1 of 2

DATE STARTED / FINISHED: 7/19/05 - 7/20/05

DRILLER: HAZ-Tech Chris Peterson

LOGGED BY: Jeff Riedel

DRILL TYPE: CME-850

GROUND SURFACE ELEVATION: 3261.4 ft

HOLE DIAMETER: 5" Casing

BOREHOLE LOCATION: 17043113.5, 919241.1

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
		1	X			3" SS	56	Saturated, Dark grayish brown [2.5Y 4/2], PEAT, PT, low to medium plasticity, loose, lots of grass, roots, and other woody organic debris present.			5			Water measured at 0.6' on 8/26/05 in piezometer A.
		2				Shelby	96	Saturated, Dark gray [2.5Y 4/1], SANDY SILT, ML, non-plastic, loose.	NPNP			59.6	68.4	Encountered groundwater at 0.7' while drilling.
		3												Penetrometer: 1.75 tsf 2.00 tsf
		4	X			2" SS	44	Saturated, Very dark gray [2.5Y 3/1], SAND, SP, non-plastic, loose, Small amount of organics in top 3", sands fine to medium grained, oxidizing to light brown.			8			
		5	X											
		6	X			3" SS	0	Loose, no recovery.			8			
		7						Saturated, Gray [10YR 5/1], SAND, SP, loose, minor amount of fibrous organics, medium grained sand.						
		8				Shelby	117							
		9	X					Saturated, Dark gray [5Y 4/1] Very dark gray [5Y 3/1], SAND, SP, non-plastic, loose, sand is medium-grained w/ organics, silty at 9.5'.			7			3 Brass liners
		10	X			3" SS	100	Saturated, Dark gray [N4], CLAY, CL, low plasticity, firm, poorly graded, fine to medium grained sand in last half of the interval.						
		11	X			2" SS	78	Saturated, Very dark gray [2.5Y 3/1], SAND, SP, non-plastic, very loose, sand fine to medium grained, oxidizing to dark brown.			2			
		12						Saturated, Dark grayish brown [2.5Y 4/2], SILT, ML, low plasticity, soft, oxidizing to light greenish brown.						
		13				Shelby	110	Saturated, Dark gray [10YR 4/1], SAND, SP, very loose, sand is medium grained with trace organics.						Water measured at 12.1' on 8/26/05 in piezometer B.
		14	X					Saturated, Very dark gray [10YR 3/1] Very dark grayish brown [2.5Y 3/2], SILT with Sand, ML, no to low plasticity, very soft, sand is fine to very fine grained.						Torvane: 0.17 tsf 0.18 tsf
		15	X			3" SS	67	Saturated, Dark gray [2.5Y 4/1], CLAY, CL, low plasticity, very soft.			0			Brass liner for 14-14.5'
		16	X					Saturated, Very dark grayish brown [2.5Y 3/2], SANDY SILT, ML, low plasticity, very soft, organics are woody, fine grained sand, oxidizing.						
		17	X			2" SS	89	Saturated, Very dark grayish brown [2.5Y 3/2], SILTY SAND, SM, very loose.			0			
		18						Saturated, Very dark grayish brown [2.5Y 3/2], SILTY SAND, SM, very loose.						
		19				Shelby	113	Saturated, Olive gray [5Y 4/2], CLAY with Sand, CL, medium plasticity.	49	26		66.1	58.0	Bottom of Shelby too disturbed for strength test.
		20						Saturated, SILT, ML, soft, some organics present.						
		21	X			3" SS	67				3			No recovery in brass liner @ 18.5'.
						2" SS	100	Saturated, Greenish gray [5GY 6/1], SILT, ML, low plasticity, very soft, no organics present.			1			Liners for 19-19.5' and 19.5-20'.



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED									
		22	X		2" SS	100	Saturated, Dark gray [10YR 4/1], ELASTIC SILT, MH, high plasticity, very soft, with rounded, coarse grained gravel at very end of tube.			1			Top 11" is slough. Top of alluvium.
		23	X		Shelby	192	Saturated, Dark grayish brown [2.5Y 4/2], GRAVEL with Silt and Sand, GP-GM, subangular to rounded, low plasticity, coarse to medium grained.						
		24	X		2" SS								Advanced 24.5-25'.
		25	X										
		26	X		2" SS	4	Saturated, Dark grayish brown [2.5Y 4/2], GRAVEL with Sand, GP, dense, classified from one piece of coarse grained gravel in nose of split spoon.			51			Coarse gravel clogged Shelby at bottom. No material entered.
		27	X										Start at 27' on 7/20/05. Advanced to 30'.
		28	X										
		29	X										
		30	X										
		31	X		3" SS	56	Saturated, Light olive brown [2.5Y 5/3], GRAVEL with Sand, GP, non-plastic, medium dense, sands are coarse grained.	NP	NP	22			Advanced 31.5-35'.
		32	X										
		33	X										Driller notes change in material at 33'. Smoothed and felt softer. Maybe finer grained alluvium.
		34	X										
		35	X										
		36	X		3" SS	28	Saturated, Light olive brown [2.5Y 5/3], GRAVEL with Sand, GP, non-plastic, loose, sands are coarse grained.	NP	NP	44			Advanced 36.5-40'.
		37	X										
		38	X				Saturated, Olive [5Y 5/6], CLAY with Sand, CL, medium to high plasticity, hard, argillaceous weathered rock for top 8", harder @ 40.6'.						Driller notes change at 37.5'. No longer feels cobbles. Bedrock probably starts at 37.5' since the recovered bedrock is weathered and soft.
		39	X										
		40	X										
		41	X		3" SS	100				42			
		42					Total Depth 41'.						
		43											
		44											



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C07

PAGE 1 of 2

DATE STARTED / FINISHED: 7/18/08 - 7/19/05

DRILLER: HAZ-Tech Chris Peterson

LOGGED BY: Jeff Riedel

DRILL TYPE: CME-850

GROUND SURFACE ELEVATION: 3262.6 ft

HOLE DIAMETER: 5" Casing

BOREHOLE LOCATION: 17042704.9, 919847.4

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		1	X			3" SS 44	Moist, Dark yellowish brown [10YR 3/4], SILTY SAND, SM, medium dense, contains abundant fibrous organics (grass, roots, bark).			29			Water encountered at 1.5'. SS was retrieved wet. Water measured at 2.3' on 8/26/05 in piezometer A.
		2	X			3" SS 3	Saturated, Very dark gray [2.5Y 3/1], SAND, SP, non-plastic, medium dense, medium to fine grained, contains trace decomposing sticks and stems.			11			
		3	X			Shelby 0	No recovery.						
		4	X			Shelby 0	No recovery.						Water measured at 7.8' on 8/26/05 in piezometer B. Touched bottom of Shelby tube material and seems loose.
		5	X			2" SS 50	Saturated, Very dark gray [2.5Y 3/1], SAND, SP, non-plastic, loose, fine to medium grained particles.			10			
		6	X			Shelby 113	Saturated, Very dark gray [2.5Y 3/1], SAND with Silt, SP-SM, non-plastic,	NPNP			94.6	27.1	
		7	X			Shelby 113	Saturated, Very dark gray [2.5Y 3/1], SAND with Silt, SP-SM, non-plastic,						Start at 12' on 7/19/05. Torvane: 0.25 tsf 0.20 tsf; Penetrometer with no adaptor: 0.75 tsf 0.6 tsf
		8	X			3" SS 0	Very Loose, no recovery.			4			
		9	X			2" SS 6	Saturated, Very dark gray [2.5Y 3/1], SAND, SP, non-plastic, very loose, fine to medium grained sand.			4			
		10	X			Shelby 113	Saturated, SILT with Sand, ML, low plasticity, soft,	40	28		70.8	49.0	Driller noted alluvium at base of Shelby. Shelby slightly bent from alluvium. Brass liner 19-19.5'
		11	X			3" SS 0	Loose, no recovery.			5			
		12	X			2" SS 100	Saturated, Very dark gray [2.5Y 3/1], SAND, SP, non-plastic, loose.			8			
		13	X			Shelby 108	Saturated, Gray [N5], SILTY SAND with Gravel, SM, angular to subangular, low to medium plasticity, loose, gravels fine.						
		14	X			3" SS 100	Saturated, Very dark gray [5Y 3/1] Gray [2.5Y 5/1], SAND, SP, non-plastic, loose, medium grained sand, second color refers to lower six inches.			56			
		15	X			2" SS 100	Saturated, Dark grayish brown [10Y 4/2], GRAVEL with Sand, GW, non-plastic, very dense, sand is medium to coarse grained.			85			
		16	X				Saturated, Dark grayish brown [10YR 4/2], GRAVEL						

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Bozeman, Montana 59715

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22	X			100	with Sand, GW, rounded, non-plastic, very dense, sands medium to coarse grained. Saturated, Dark grayish brown [10YR 4/2], GRAVEL with Sand, GW, rounded, non-plastic, very dense, sands medium to coarse grained. (Continued)			85			Driller notes cobbles throughout advance.
		25	X			2" SS	Saturated, Brown [10YR 4/3], GRAVEL with Silt and Sand, GW-GM, non-plastic, very dense, gravels fine grained and rounded.			100			Driller suspects bedrock at 27.5'. Pullout auger and try 3" SS to verify. 75 blows/ 5.5" @ 27.5'. Core 27.5'-30.5'; RQD=0 - Top 5.5" of core disturbed from 3" SS. Core bit advanced fast for rock.
		28	X			3" SS	Greenish gray [5GY 6/1], soft, foliated, probably bedrock, broken fraction has low plasticity, fine grained.			100			Core 30.5'-32'; RQD=0 - Advance was slower through relatively harder material. Core 32'-35.5'; RQD = 0
		29				Core	Core, 27.5'-30.5': No Recovery. Cuttings, coarse grained, angular, flaky particles.						
		30				Core	Core, 30.5'-32': Soft and incompetent argillitic rock, foliated.						
		31				Core	Core, 32'-35.5': Very discontinuous bedrock/argillite, foliated at 45-60 degrees to horizontal, core is complete but soft and easily broken into particles with size between fines and 1/4", able to break with fingers.						
		32				Core							
		33				Core							
		34				Core							
		35				Core							
		36					Total Depth 35.5'.						
		37											
		38											
		39											
		40											
		41											
		42											
		43											
		44											



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PROJECT NAME: Milltown Dam

Drill Hole No. EM-C08

PAGE 1 of 2

DATE STARTED / FINISHED: 7/20/05 - 7/21/05

DRILLER: HAZ-Tech Chris Peterson

LOGGED BY: Jeff Riedel

DRILL TYPE: CME-850

GROUND SURFACE ELEVATION: 3262.6 ft

HOLE DIAMETER: 5" Casing

BOREHOLE LOCATION: 17043407.2, 918892.8

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
		1	X			3" SS	44	Moist, Brown [7.5YR 4/2] Olive brown [2.5Y 4/3], SILT with Sand, OL, no to low plasticity, loose, brass liner (0-0.5'); sand is fine to very fine grained with trace organics, brass liner (0.5-1'): silt with sand on top with a med-high plasticity clay with organics on the bottom, second color refers to last 6".			8			Water measured at 2.7' on 8/26/05 in piezometer A.
		2	X			Shelby	0	Moist, Dark grayish brown [10Y 4/2], SILT with Sand, ML, no to low plasticity, soft, sand is fine grained, organics (roots, sticks).						
		3	X											
		4	X			3" SS	83	Moist, Very dark grayish brown [10YR 3/2], SAND, SP, non-plastic, very loose, very fine-grained sand.	52	31	3	77.0	43.4	Ziplock 3.5-4' Brass liner- 4-4.5' Encountered ground water at 4' while drilling. Brass liner- 4.5-5' Brass liner- 5-5.5' Ziplock 5.5-6.5'
		5	X					Saturated, Gray [2.5Y 5/1], ELASTIC SILT, MH, high plasticity, soft.						
		6	X			3" SS	56	Saturated, Gray [2.5Y 5/1], SAND with Silt, SP-SM, non-plastic, very loose, sand is fine grained.	NP	NP	3			
		7	X					Saturated, Gray [2.5Y 5/1], SAND with Silt, SP-SM, non-plastic, loose to very loose, medium grained.	NP	NP				Probably loose sands.
		8	X			Shelby	63							
		9	X			3" SS	0				5			
		10	X											Probably loose sands.
		11	X			3" SS	0				2			
		12	X					Saturated, Gray [2.5Y 5/1], ELASTIC SILT, MH, high plasticity, soft.	59	31		61.2	63.4	
		13	X			Shelby	113							Brass liner - 13.5-14' Brass liner - 14-14.5' Brass liner = 14.5-15' Water measured at 2.7' on 8/26/05 in piezometer B.
		14	X			3" SS	100	Saturated, Gray [N5], ELASTIC SILT, MH, soft, high plasticity silt on top, sand with a little clay at about 14', med to high plasticity clay with a little organic matter at about 14.5'.			4			
		15	X					Saturated, Olive gray [5Y 4/2], SILTY SAND, SP-SM, non-plastic, very loose, fine grained particles, density refers to bottom 18".	NP	NP		96.9	27.1	
		16	X			Shelby	115							Advanced through cobble. Advanced to 25'.
		17	X											
		18	X			2" SS	100				4			
		19	X					Saturated, Brown [10YR 4/3], SILTY SAND, SM, medium dense, fine grained particles.			17			
		20	X			3" SS	83	Saturated, Grayish brown [10YR 5/2], GRAVEL with Silt and Sand, GP-GM, non-plastic, medium dense.						
		21	X											



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22					Saturated, Grayish brown [10YR 5/2], GRAVEL with Silt and Sand, GP-GM, non-plastic, medium dense. (Continued)						Cobbles rough drilling Drilling much smoother at 24'. Start at 27' on 7/21/05. Driller notes gravels during advance from 27-30'. Driller notes some gravels. Top of bedrock Advance to 40'.
		23											
		24											
		25					Saturated, SAND with Silt, SP-SM, non-plastic, medium dense, medium grained.						
		26											
		27											
		28					Saturated, SAND, SP, non-plastic, medium dense, medium grained.						
		29											
		30											
		31					Saturated, GRAVEL with Silt and Sand, GP-GM, dense, greenish gray rock flour, dark gray to green bedrock, particles recovered are gravel sized and angular, suspect weathered argillaceous bedrock.						
		32											
		33											
		34					Total Depth 41.5'.						
		35											
		36											
		37											
		38											
		39											
		40											
		41											
		42											
		43											
		44											



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PROJECT NAME: Milltown Dam

Drill Hole No. EM-C09

PAGE 1 of 3

DATE STARTED / FINISHED: 7/28/05 - 7/28/05

DRILLER: HAZ-Tech Chris Peterson

LOGGED BY: Kagan Rutz

DRILL TYPE: CME-850

GROUND SURFACE ELEVATION: 3261.8 ft

HOLE DIAMETER: 5" Casing

BOREHOLE LOCATION: 17042900.8, 919557.2

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		1	X			3" SS 67	Moist, Olive brown [2.5Y 4/3], ORGANIC SANDY SILT, OL, subrounded, low to medium plasticity, loose, some surface gravels.			7			Water measured at 1.6' on 8/26/05 in piezometer A.
		2	X			2" SS 94	Moist, Grayish brown [2.5Y 5/2], SILTY SAND, SM, medium dense, with some organics in top 2" of sampler.			16			
		3	X				Loose.						Try a 3" with liners.
		4	X			3" SS 100				8			
		5	X				Saturated, SAND with Silt, SP-SM, non-plastic, very loose,						Sand in end of shelly- no torvane or pen test.
		6	X			Shelby 100		NP NP		86.7	36.2		
		7	X				No recovery in spoon.						Water measured at 7.7' on 8/26/05 in piezometer B.
		8	X			3" SS 0				2			
		9	X			2" SS 44	Saturated, Olive gray [5Y 4/2] Dark grayish brown [2.5Y 4/2], SILTY SAND, SM, non-plastic, very loose, with some organics.			4			Torvane = 0.2 tsf 0.17 tsf; penetrometer = 0.5 tsf
		10	X				Saturated, SILT with Sand, ML, low plasticity, soft.						
		11	X			Shelby 100		40 27		65.9	55.0		Torvane = 0.15 tsf; penetrometer = 0.1 tsf
		12	X			3" SS 100	Saturated, SILT, ML, low plasticity, soft.	45 31		3	66.4 54.6		
		13	X								66.3 56.7		Organics consist of wood and organic silt.
		14	X			2" SS 67	Saturated, Dark grayish brown [2.5Y 4/2], SILTY SAND, SM, no to low plasticity, soft, organics present.			3			
		15	X				Saturated, SILT with Sand, ML, low plasticity, soft.						Torvane = 0.25 tsf 0.21 tsf 0.28 tsf; pen = 1 tsf 0.75 tsf 1.25 tsf
		16	X			Shelby 100		41 29		69.9	52.0		
		17	X				Saturated, Dark grayish brown [2.5Y 4/2] Dark olive gray [5Y 3/2], SILTY SAND, SM, non-plastic, first 18" is loose, last 12" is dense, second color for first 6", with transition into alluvium at 19.5'.			4			Gas assumed to be methane gas is bubbling up around auger starting at
		18	X			3" SS 83							
		19	X			2" SS 78				33			
		20	X			2" SS 42	Saturated, Dark grayish brown [2.5Y 4/2] Olive brown [2.5Y 4/3], GRAVEL with Silt and Sand, GP-GM, subangular, very dense, 2nd color refers to first 6".			72			
		21	X										



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
Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

DRILL HOLE LOG MILLTOWN DAM.GPJ PIEDMONT.GDT 11/1/05



PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45	X			3" SS	Medium dense to dense, no recovery in spoon. Total Depth 45'.			100			177 blows for 2" @ 45'. Driller reports bedrock at 45'. Extremely difficult to auger.
		46											
		47											
		48											
		49											
		50											
		51											
		52											
		53											
		54											
		55											
		56											
		57											
		58											
		59											
		60											
		61											
		62											
		63											
		64											
		65											
		66											
		67											



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C10

PAGE 1 of 2

DATE STARTED / FINISHED: 7/18/05 - 7/18/05

DRILLER: HAZ-Tech Chris Peterson

LOGGED BY: Jeff Riedel and Dan McCaffery

DRILL TYPE: CME-850

GROUND SURFACE ELEVATION: 3261.6 ft

HOLE DIAMETER: 5" Casing

BOREHOLE LOCATION: 17042333.3, 920361.7

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		1				56	Moist, Dark brown [7.5YR 3/3], ORGANIC CLAY, OL, no to low plasticity, hard, top soil w/ humus, highly organic soil.			93			
		2				33	Saturated, Very dark grayish brown [2.5Y 3/2] Black [2.5Y 2.5/1], SILT, ML, low to medium plasticity, hard, 2nd color refers to second half of interval, silt becomes more plastic (med-high) and has firm consistency in lower half of interval.			35			Water @ 1'8" BSS (Below Sediment Surface).
		3											Water measured at 2.7' in piezometer A on 8/26/05.
		4				78				7			Brass liners had catcher.
		5					Saturated, Black [2.5Y 2.5/1], ORGANIC SILT with SAND, OL, non-plastic, soft.						
		6				92	Saturated, Black [2.5Y 2.5/1], ORGANIC SILTY SAND, SM, loose.	NP 46	NP 34		85.1 63.0	37.1 64.3	Good place for piezometer (6-7').
		7											
		8				67	Saturated, Very dark gray [2.5Y 3/1], SILT, ML, medium plasticity, firm.			5			
		9				28	Saturated, Very dark gray [2.5Y 3/1], SILTY SAND, SM, no to low plasticity, medium dense, coarse sand grains and silts.			19			Water measured at 9.3' in piezometer B on 8/26/05.
		10					Saturated, Black [2.5Y 2.5/1], GRAVEL with Sand, GP, subrounded, non-plastic, medium dense.						3/4" Gravel in SS
		11				17				15			
		12											Fine gravels (very small amount) left in SS.
		13				0				11			Advanced 13.5-15'.
		14											
		15					Saturated, Black [2.5Y 2.5/1], SAND with Gravel, SP, subrounded, non-plastic, medium dense, coarse sand, fine gravels present.						1" diameter gravel in SS
		16				13				19			
		17											Advanced 17-20'.
		18											
		19											
		20											
		21				71				30			



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DRILL HOLE LOG: MILLTOWN DAM.GPJ, PIEDMONT.GDT 11/1/05

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
		22	X			2" SS	71	Saturated, Pale olive [5Y 6/3], GRAVEL with Sand, GW-GM, subrounded, medium dense, sand fine to coarse grained, fine gravels. (Continued)			30			Advanced 22-25'.
		23												
		24												
		25	X			3" SS	80	Light olive gray [5Y 6/2], GRAVEL with Clay and Sand, GW-GC, angular to subangular, very dense, weathered mudstone/argillite, clay has medium plasticity.			82			Advanced 26.5-30'.
		26												
		27												
		28												
		29												
		30	X			3" SS	91	Light olive brown [2.5Y 5/3], SAND with Gravel, SP, angular, very dense, layered, soft, broken fines have low plasticity, probably weathered argillite. Total Depth 30.5'.			71			5 1/2" Blows on bedrock SS bounced repeatedly.
		31												
		32												
		33												
		34												
		35												
		36												
		37												
		38												
		39												
		40												
		41												
		42												
		43												
		44												



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C11

PAGE 1 of 2

DATE STARTED / FINISHED: 7/27/05 - 7/27/05

DRILLER: HAZ-Tech Chris Peterson

LOGGED BY: Kagan Rutz

DRILL TYPE: CME-850

GROUND SURFACE ELEVATION: 3261.5 ft

HOLE DIAMETER: 5" Casing

BOREHOLE LOCATION: 17043658.8, 918654.6

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED									
		1			Shelby	58	Black [2.5Y 2.5/1], ORGANIC SILT, OL, with minor root structures.						Torvane = 0.2 tsf; Penetrometer = 1.0 tsf
		2											Water measured at 1.6' on 8/26/05 in piezometer A.
		3			3" SS	19	Wet, Dark grayish brown [10YR 4/2], ORGANIC SANDY SILT, OL, non-plastic, very loose, sand fine grained, abundant roots and decomposing fibrous organics.			4			Try 3" SS with brass liners. Torvane = 0.16 tsf; Penetrometer = 0.75 tsf
		4			2" SS	100	Wet, Very dark gray [2.5Y 3/1], SANDY SILT, ML, no to low plasticity, medium dense, sand is very fine grained.			11			Organics to 4'.
		5					Wet, Dark grayish brown [2.5Y 4/2], SAND, SP, non-plastic, loose to medium dense, sand medium grained.						Bottom of Shelby tube shows clean fine-grained sand.
		6			Shelby	113	Transition to a greenish gray, poorly graded sand (SP), very fine-grained.						
		7					Very loose, no recovery.						No recovery. 3" SS with liners.
		8			3" SS	0				3			
		9			2" SS	44	Saturated, Dark gray [5Y 4/1], SILTY SAND, SM, non-plastic, very loose, very fine grained.			0			Weight of hammer pushes sampler 18".
		10					Saturated, Greenish gray [5GB 6/1], CLAY, CH, high plasticity, very soft.						10': Torvane = 0.25 tsf (2x); penetrometer = 0.5 tsf (4 tests)
		11			Shelby	108		50	27		66.2	60.3	
		12					Saturated, Greenish gray [5GB 6/1], CLAY, CH, high plasticity, very soft.	62	31		60.9	64.0	12': Torvane = 0.18 tsf 0.25 tsf; penetrometer = 0.4 tsf (3x); 3 liners taken.
		13			3" SS	100	Saturated, Greenish gray [5GB 6/1], ELASTIC SILT, MH, high plasticity, very soft.	61	31	1	64.8	58.7	
		14			2" SS	100	Saturated, Very dark gray [2.5Y 3/1], SANDY SILT, ML, low plasticity, firm, sand is very fine grained, with a transition to dark olive brown silty sand from 14.8-15'.			5			Transition to dark brown silty sand (SM) at 14.8'. Water measured at 14.3' on 8/26/05 in piezometer B.
		15											15': Penetrometer = 0.5 tsf 0.5 tsf 0.75 tsf
		16			Shelby	108		NP	NP		83.4	38.5	
		17					Saturated, Brown [7.5YR 4/2], SILT, ML, low to medium plasticity, soft, some clay, some sand, and some organics present, transitions to a clay, CL, with some wood and organic content at end of interval.			4			Torvane = 0.27 tsf 0.24 tsf; penetrometer = 0.5 tsf 0.6 tsf; 3 liners taken.
		18			3" SS	100							
		19			2" SS	100				7			
		20					Saturated, Dark gray [10YR 4/1], SAND, SP, non-plastic, loose, sand is fine grained.						20': pushes Shelby tube 0.75"; single 3.5" cobble in end of sample.
		21			Shelby	100							



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DRILL HOLE LOG, MILLTOWN DAM, GP-1, PIEDMONT, GDT, 11/1/05

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22	X			61	Saturated, Dusky red [2.5YR 4/2], GRAVEL with Silt and Sand, GW-GM, subrounded, non-plastic, very dense, coarse grained sand. (Continued)			98			Transition into alluvium @ 21.5'; auger 20.75'-25' through alluvial gravel.
		23											
		24											
		25	X			42	Saturated, Grayish brown [10YR 5/2], GRAVEL with Sand, GP, low to medium plasticity, very dense, fine to coarse gravels, rounded to angular, mixed lithology.	NPNP		69			Broke cobble in end of sampler.
		26											
		27											Mixed lithology. Auger 27-30' through alluvium.
		28											
		29											
		30	X			19	Saturated, Light brownish gray [2.5Y 6/2], GRAVEL with Sand, GP, medium dense, with cobbles, sand is coarse grained and gravels are rounded.			16			Pushes 4" cobble. Only 3" of recovery.
		31											
		32											
		33					very dense, No recovery, suspect bedrock encountered.						Driller reports possible bedrock encounter at 33.0'.
		34					Total Depth 35'.						
		35				0				100			
		36											
		37											
		38											
		39											
		40											
		41											
		42											
		43											
		44											

This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.



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ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C12

PAGE 1 of 3

DATE STARTED / FINISHED: 7/19/05 - 7/19/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3282.6 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17042807.3, 919904.2

HAMMER TYPE: 140# Automatic Trip Hammer

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
								Top soil.						
		1						Dry, Brown [10YR 4/3], GRAVEL with Silt, GW-GM, angular to subrounded, non-plastic, very dense, trace fine stems from 2-3.5'.						Advanced 3.5-5' through gravels.
		2												
		3				2" SS	56				97			
		4												
		5						Moist, Brown [10YR 4/3], GRAVEL with Silt and Sand, GW-GM, angular to subrounded, non-plastic, very dense, sand fraction is medium grained, sediment is very dense for first half of sample, and sediment is dense for second half of interval.						Advanced 6.6-10'. Driller feels boulders while advancing.
		6				2" SS	56				74			
		7												
		8												
		9						Moist to wet, Brown [7.5YR 4/3], GRAVEL with Silt and Sand, GW-GM, subrounded, non-plastic, loose to medium dense, sand is medium grained, sediment is loose for first half and medium dense for second half of interval.						Advanced 11.5-15'. Driller feels softer gravels at 13'.
		10				2" SS	56				32			
		11												
		12												
		13						Moist to wet, Brown [7.5YR 4/3], GRAVEL with Silt and Sand, GW-GM, subrounded, non-plastic, loose to medium dense, sand is medium grained, sediment is loose for first half and medium dense for second half of interval.						Advanced through loose gravels from 16.5-20'.
		14												
		15				2" SS	22				7			
		16												
		17												
		18												
		19												
		20				2" SS	44				11			
		21												



PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

CLIENT: Emc2

ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

DRILL HOLE LOG MILLTOWN DAM.GPJ, PIEDMONT.GDT 11/1/05

 **PIEDMONT ENGINEERING, Inc.**
1215 Apple's War Bolgrade, Montana 59714

PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45					Saturated, Olive gray [5Y 4/2] Grayish brown [10YR 5/2], GRAVEL with Sand, GW, subangular to rounded, non-plastic, medium dense, sand fraction is coarse grained. 2nd color refers to 50'-55' interval. (Continued)						26 blows caused by a rock.
		46				2" SS 56				20			
		47											Advanced through gravel @ 46.9-50'.
		48											
		49											
		50					Saturated, Dark grayish brown [10Y 4/2], GRAVEL with Sand, GW, rounded, non-plastic, medium dense to dense, sand is coarse grained.						Advanced through gravels @ 51.5-55'.
		51				2" SS 50				26			
		52											
		53											
		54											
		55					Dense.						Advanced through gravels @ 56.6-60'.
		56				2" SS 33				16			
		57											
		58											
		59											
		60					Color change to Dark grayish brown [2.5Y 4/2], Very dense.						Advanced 61.5-65'.
		61				2" SS 44				37			
		62											
		63											
		64											
		65				2" SS 100	Light olive brown [2.5Y 5/4], CLAYEY GRAVEL with Sand, GC, low to medium plasticity, very dense, angular argillite in clay, likely weathered bedrock.						Total Depth 66'
		66				2" SS 100				100			
		67											



PIEDMONT ENGINEERING, Inc.
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CLIENT: Emc2

ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C14

PAGE 1 of 4

DATE STARTED / FINISHED: 7/30/05 - 7/30/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3290.2 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17043723.7, 918829.7

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
							Asphalt.						
		1					Moist, Brown [7.5YR 5/3], SAND with Gravel, SP, subangular to rounded, non-plastic, very dense, rounded gravels and fractured from spoon.						
		2											
		3	X			2" SS	61			72			Advanced in gravel 4-5'
		4	X										
		5	X			2" SS	40			100			Advanced in gravels and cobbles 6.5-10'.
		6	X				Moist, Reddish brown [5YR 5/3], SAND with Gravel, SW, subrounded, non-plastic, very dense.						
		7											
		8											
		9											
		10	X			2" SS	67			40			Advanced through gravels and cobbles 11.5-15'.
		11	X				Moist, Brown [7.5YR 5/3], SAND with Gravel, SP, non-plastic, dense, gravels subrounded and fractured from spoon.						
		12											
		13											
		14											
		15	X			2" SS	0			100			Advanced 15.5-20' in gravels and cobbles.
		16					GRAVEL with Sand, GP, very dense, no recovery.						
		17											
		18											
		19											
		20	X			2" SS	40			100			
		21											

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1215 Apple's Way Belgrade, Montana 59714

CLIENT: Emc2

ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22					GRAVEL, GP, angular to subangular, very dense, no recovery or not enough recovery to describe. One broken 2" gravel in spoon. (Continued)						Advanced in gravels with cobbles 20.5-25'.
		23											
		24											
		25	X			100	2" SS Moist, Pale brown [10YR 6/3], GRAVEL with Silt and Sand, GP-GM, angular to subangular, non-plastic, very dense, gravels rounded and fractured from spoon, sand is medium grained.			100			Advanced through dense gravels and cobbles 25.5-30'. 45 minutes downtime to replace auger head which was worn from boulders/cobbles.
		26											
		27											
		28											
		29											
		30				0	2" SS Very dense, no recovery.			100			Advanced in very dese gravel with cobbles 30-35'.
		31											
		32											
		33											
		34											
		35	X			69	2" SS Moist, Pinkish gray [5YR 6/2], GRAVEL with Silt and Sand, GP-GM, angular to subrounded, very dense, gravels rounded but most are fractured from split spoon.			94			
		36											
		37											
		38											
		39	X			39	3"SS Moist to wet, Light reddish brown [5YR 6/3], GRAVEL with Sand, GW, angular to subrounded, dense, gravels rounded to angular and fractured from spoon.			37			Driller feels softer material at 38.5' while advancing. Tried Shelby tube at 38.5' but crushed and no recovery.
		40	X										
		41	X			61	2" SS Moist, Reddish brown [5YR 5/3], SAND with Silt, SW-SM, subrounded, medium dense. Moist, GRAVEL with Sand, GP, non-plastic, medium dense.			28			Material removed from liner since it is gravel and disturbed. While advancing augers at 40-41' the cutting caved into hole and locked augers. Water introduced to outside of augers.
		42											
		43											
		44											



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PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45					Moist, GRAVEL with Sand, GP, non-plastic, medium dense. (Continued)						Water measured at 43.8' on 8/26/05 in piezometer B. Advanced 41.5-45' in gravel with cobbles. Samples may be wet from water introduced to augers. Advanced 46.5-50' through gravel.
		46				2" SS 44	Saturated, Brown [7.5YR 5/3], GRAVEL with Sand, GP, subangular to subrounded, non-plastic, medium dense, gravels are rounded.			25			
		47											
		48											3 blows @ 50' from slough. Advanced 51.5-55' in gravels.
		49											
		50				2" SS 44	Saturated, Brown [7.5YR 4/4], GRAVEL with Sand, GP, non-plastic, medium dense, gravels are rounded.			26			
		51											Shelby tube bottom crushed. No hand penetrometer.
		52											
		53											
		54											Advanced 59.5-60'.
		55				2" SS 72	Saturated, Pale brown [10YR 6/3], GRAVEL with Clay and Sand, GP-GC, medium dense, transition to very stiff to hard clay.			22			
		56					Saturated, Pinkish gray [7.5YR 6/2], CLAY with Sand, CL, very stiff, medium grained sand.	31	18				
		57				Shelby 80							Advanced 61.5-65' in gravel.
		58											
		59				2" SS 72	Saturated, Grayish brown [10YR 5/2], GRAVEL with Clay and Sand, GP-GC, no to low plasticity, medium dense, rounded gravels.			18			
		60					Saturated, Brown [10YR 4/3], SAND, SP, transitioning from medium dense to loose.						
		61				2" SS 83				7			
		62					Saturated, Light brownish gray [10YR 6/2], SAND with Gravel, SP, rounded, non-plastic, loose, medium grained sand.						
		63											
		64											
		65											
		66				2" SS 44	Saturated, Pale brown [10YR 6/3], SAND with Gravel, SP, subrounded, non-plastic, loose.			5			
		67											




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PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		68					Saturated, Pale brown [10YR 6/3], SAND with Gravel, SP, subrounded, non-plastic, loose. (Continued)						Advanced 66.5-69'. Driller feels bedrock at 68'.
		69				2" SS 100	Moist, Dark grayish brown [10Y 4/2], SILT with Sand, ML, non-plastic, very dense, sand is very fine grained, suspect weathered argillaceous bedrock.			100			
		70					Total Depth 69'.						
		71											
		72											
		73											
		74											
		75											
		76											
		77											
		78											
		79											
		80											
		81											
		82											
		83											
		84											
		85											
		86											
		87											
		88											
		89											
		90											



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CLIENT: Emc2

ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C15

PAGE 1 of 4

DATE STARTED / FINISHED: 7/27/05 - 7/27/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3299.7 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17044007.4, 918526.7

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		1					Dry, Gray [2.5Y 5/1], GRAVEL with Sand, GP, subrounded, non-plastic, very dense, sand is very fine grained.						
		2											
		3				2" SS 22				80			Rock clogged split spoon.
		4											Advanced in gravels 3.5-5'.
		5					Moist, Reddish brown [5YR 5/3], GRAVEL with Sand, GP, subangular, non-plastic, dense, sand is medium to fine grained, cuttings were gravel with silt.						
		6				2" SS 17				33			
		7											Advanced in gravels 6.5-10'. Driller noted boulder at 8'.
		8											
		9					Moist, Dark reddish gray [5YR 4/2], GRAVEL with Sand, GP, subangular to subrounded, non-plastic, very dense, gravels are subrounded and fractured by split spoon, sand is medium to fine grained.						
		10				2" SS 67				64			
		11											Advanced through gravels and boulders 11.5-15'.
		12											
		13					Color change to Reddish brown [5YR 4/2]. Dense.						
		14											
		15				2" SS 72				40			
		16											Advanced through gravels 16.5-20'.
		17											
		18											
		19											
		20				2" SS 61				46			
		21											

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PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
								MATERIAL DESCRIPTION						
		22	X			2" SS	61	Moist, Reddish brown [5YR 4/3], GRAVEL with Sand, GP, non-plastic, dense, gravels are fractured by spoon, sand is medium to coarse grained. (Continued)			46			Advanced through gravel 21.5-25'.
		23												
		24												
		25	X			2" SS	67	Moist, Light brown [7.5YR 6/3], GRAVEL, GP, subrounded, non-plastic, very dense, gravel fractured by spoon.			56			Advanced 26.5-30' in gravels.
		26												
		27												
		28												
		29												
		30	X			2" SS	0	Medium dense, no recovery. Rock in sampler bit.			26			Advanced 31.5-35' in many boulders.
		31												
		32												
		33												
		34												
		35	X			2" SS	0	Very dense, no recovery.			100			Advanced 36.5-40'. At 38.5' material became softer but still contains gravels/boulders.
		36												Water measured at 38.7' on 8/26/05 in piezometer A.
		37												Pushed Shelby tube 3" then refusal (40-40.25'). Material is wet sandy gravel. 3" split spoon used after refusal of Shelby.
		38												Advanced 41.5-44' in gravel.
		39												
		40	X			3" SS	28	Saturated, Brown [7.5YR 5/2], GRAVEL, GW, rounded, non-plastic, medium dense.			11			
		41												
		42												
		43												
		44												



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PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
								This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.						
		45				Shelby	100	Saturated, Dark gray [2.5Y 4/1], SILTY SAND, SM, non-plastic, very dense. (Continued)	NP	NP		68.9	49.9	
		46				2" SS	61	Saturated, Brown [7.5YR 4/2], SAND, SW, non-plastic, medium dense, sand is medium to fine grained.			14			Readings at 49.5': hand pen = 3.5; 3.25; 3.5 tsf; torvane = 0.35tsf
		47												
		48				Shelby	100	Saturated, Dark gray [2.5Y 4/1], SILTY SAND, SM, no to low plasticity, very stiff, poorly graded sand with silt from 48.3-49', silt @ 49', organics present.	NP	NP		82.3	36.0	
		49							NP	NP	40			
		50				3" SS w/ liners	100	Saturated, Dark gray [2.5Y 4/1], SANDY SILT, ML, non-plastic, loose, few organics present.			7			Readings at 49.5': hand pen = 4.25; 4.1; 4.3 tsf; torvane = 0.4 tsf
		51							NP	NP				Readings at 50': hand pen = 3.25; 3.5; 3 tsf; torvane = 0.4 tsf
		52				2" SS	100	Saturated, Very dark grayish brown [10YR 3/2], CLAY with Silt, CL, medium plasticity, firm.			7			
		53												
		54				Shelby	100	Saturated, Light gray [2.5Y 7/1], SILT with Sand, ML, no to low plasticity, stiff.	NP	NP	46	79.3	42.3	Readings at 54.5': hand pen = 3.25; 3.5; 3 tsf; no torvane
		55				2" SS	100	Saturated, Dark gray [N4], ELASTIC SILT, MH, high plasticity, firm, very fine sand on outside of sample.			6			Readings at 55.5': hand pen = 1.25; 1.75; 2.25 tsf
		56				Shelby	100	Saturated, Dark gray [2.5Y 4/1], SILT with Sand, ML, low plasticity, very stiff, organics present.	33	27		90.6	30.1	
		57												Readings at 57.25': hand pen = 4.0; 2.75; 3.25 tsf
		58				2" SS	83	Saturated, Very dark grayish brown [10YR 3/2], SAND with Silt, SP-SM, low to medium plasticity, loose, upper 1" gray clay; then, loose, dark gray, low plasticity silt with sand becoming more sandy with depth, bottom 6" has slow dilatancy.			8			
		59				2" SS	100	Saturated, Very dark gray [10YR 3/1], SAND with Silt, SP-SM, non-plastic, loose, sand is very fine grained.			5			
		60												
		61				Shelby	0	No recovery.						Water measured at 38.7' on 8/26/05 in piezometer B.
		62												
		63				2" SS	100	Saturated, Dark gray [10YR 4/1], SAND with Silt, SP-SM, no to low plasticity, loose, sand is very fine grained.			6			
		64												
		65				3" SS	94	Saturated, Olive gray [5Y 4/2], SAND with Silt, SP-SM, non-plastic, loose, sand is medium to fine grained.			5			
		66				2" SS	56				63			
		67												



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PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED								
		68				Saturated, Reddish gray [5YR 5/2], GRAVEL with Sand, GP, angular to subrounded, no to low plasticity, very dense, gravels are well rounded and fractured from spoon. (Continued)						Advanced 67-70'.
		69										
		70										
		71			2" SS 33	Saturated, Yellowish brown [10YR 5/4], GRAVEL with Sand, GP, angular to subrounded, dense for the first half of interval, very dense for second half of interval			32			
		72										
		73										
		74										
		75										
		76			2" SS 0	no recovery - slough in spoon.			100			Advancing 71.5-75'.
		77			2" SS 100	Gray [2.5Y 5/1], CLAYEY SAND with Gravel, very dense, fragments of bedrock are angular to subangular sand and clay size particles, finer particles have low plasticity.			100			Driller reports bedrock at 76.9'.
		78										
		79				Total Depth 77.3'.						
		80										
		81										
		82										
		83										
		84										
		85										
		86										
		87										
		88										
		89										
		90										



PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

CLIENT: Emc2

ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C17

PAGE 1 of 3

DATE STARTED / FINISHED: 7/23/05 - 7/24/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Jeff Riedel

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3310.6 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17044375.1, 918208

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK									
								This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.						
								Drilling pad constructed from alluvial fill.						
		1				2" SS	67	Moist, Brown [10YR 4/3] Brown [10YR 5/3], GRAVEL with Sand, GP, subangular to rounded, non-plastic, dense, gravels are rounded and angular, angularity is from blows from split spoon, 2nd color for first 2.5'.			48			
		2												
		3				2" SS	67				50			
		4												
		5												
		6				2" SS	67							
		7												
		8												
		9												Advance to 10 ft. Note cobbles during advance.
		10												
		11				2" SS	33	Moist, Grayish brown [10YR 5/2], SAND with Silt and Gravel, SW-SM, rounded, non-plastic, loose, sand fraction is coarse to fine grained.			8			9': material loosened but still felt gravelly.
		12												
		13												
		14												
		15				2" SS	22	Moist, Brown [10YR 5/3], GRAVEL with Sand, GP, rounded, loose for first half of interval, medium dense for second half of interval, sand fraction is coarse to fine grained, medium dense at 20'.			9			
		16												
		17												
		18												
		19												
		20				2" SS	39				21			Driller notes softer at 18.5' still gravels though.
		21												



PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

CLIENT: Emc2

ADDRESS: 205 Haggerty Lane, Suite 120

Bozeman, Montana 59715

PHONE NUMBER: 406-522-0251



PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		45	X			83	Moist, Pale brown [10YR 6/3], SAND with Silt, SP-SM, non-plastic, dense.			35			Driller stopped Shelby because he "felt competent material"; pen = 1 tsf 0.75 tsf for top 10" 45.25' Top of alluvium
		46	X				Moist, Light yellowish brown [2.5Y 6/3], GRAVEL with Sand, GP, non-plastic, dense, broken round gravels.						
		47											Driller notes material softened. Stopped advance to take 3" SS @ 48.5'.
		48											
		49	X			78	Moist, Olive brown [2.5Y 4/3], GRAVEL with Sand, GW, non-plastic, medium dense.			15			
		50	X										
		51	X			67	Moist, Brown [10YR 5/3] Light brown [7.5YR 6/3], GRAVEL with Silt and Sand, GP-GM, subangular to subrounded, non-plastic, medium dense, broken gravels, probably broken by SS, sand fraction is medium to fine grained, color lightens in last half of interval.			23			
		52											
		53											
		54											
		55	X										
		56	X			67				25			
		57											
		58											
		59											
		60	X										
		61					Very dense, broken pilot bit in hole, cannot advance past.			100			105 blows/5" - Boulder
		62					Redrilled in EM-C17B, which is 5 feet east of EM-C17.						
		63					Total Depth 60'.						
		64											
		65											
		66											
		67											



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PROJECT NAME: Milltown Dam

Drill Hole No. EM-C17B

PAGE 1 of 4

DATE STARTED / FINISHED: 7/25/05 - 7/26/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Jeff Riedel


DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3310.6 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17044375.1, 918208

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING	
			DRIVE	UNDISTURBED	BULK									
		1					Broken pilot bit in hole and can not advance past, so redrilling EM-C17 5 feet to the east as EM-C17B. Advance to 41.5'.							
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												
		11												
		12												
		13												
		14												
		15												
		16												
		17												
		18												
		19												
		20												
		21												



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22					Advance to 41.5'						
		23											
		24											
		25											
		26											
		27											
		28											
		29											
		30											
		31											
		32											
		33											
		34											
		35											
		36											
		37											
		38											
		39											
		40											
		41											41": Drilling became very easy and possible indication of finer-grained material layer.
		42					Try Shelby- refusal Try 3" SS wth brass liners.						Shelby came out bent. Advance felt very soft to 45'. Try Shelby.
		43											
		44											



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DRILL HOLE LOG MILLTOWN DAM.GPJ PIEDMONT.GDT 11/1/05

PHONE NUMBER: 406-522-0251

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		68					Moist, Pinkish gray [5YR 7/2], GRAVEL with Sand, GW, angular, non-plastic, very dense, gravels fractured from spoon, sand is medium to coarse grained and poorly graded. (Continued)						Advanced 65-68.5' assumed gravel but driller has a difficult time feeling the different material types when case advancing.
		69	X			2" SS 64	Moist, Reddish brown [5YR 5/3], GRAVEL with Sand, GP, angular to subrounded, non-plastic, dense to very dense, gravels fractured from spoon, sand is medium to coarse grained and poorly graded.			74			
		70											Most likely encountered water table 69-73' based on blow counts. Driller using polymer for casing advancing since 60'. Well sounder indicates the water level is 74.8' below the surface. Water measured at 75.3' on 8/26/05 in piezometer B.
		71											
		72											
		73											
		74	X			2" SS 56				35			
		75											
		76											
		77											
		78											
		79	X			2" SS 56	Saturated, Brown [7.5YR 5/3] Light reddish brown [5YR 6/3], GRAVEL with Sand, GW, subangular to subrounded, non-plastic, dense, sand is medium to coarse grained and poorly graded, for last half of interval, sand is fine to coarse grained, 2nd color is for last half of interval.			33			
		80											
		81											
		82											
		83											
		84	X			2" SS 61				33			
		85											
		86											
		87											
		88											
		89	X			2" SS 50	Saturated, Reddish brown [5YR 5/3], GRAVEL with Sand, GP, subangular to subrounded, non-plastic, dense, sand is coarse grained and poorly graded Total depth 90'.			31			Total Depth 90'.
		90											



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PHONE NUMBER: 406-522-0251

PROJECT NAME: Milltown Dam

Drill Hole No. EM-C21

PAGE 1 of 4

DATE STARTED / FINISHED: 7/28/05 - 7/29/05

DRILLER: HAZ-Tech Mike Corn

LOGGED BY: Ryan Norkoli

DRILL TYPE: BK-81

GROUND SURFACE ELEVATION: 3302.8 ft

HOLE DIAMETER: 4 1/4" ID Hollow Stem Auger

BOREHOLE LOCATION: 17044093.4, 918455.5

HAMMER TYPE: 140# Automatic Trip Hammer

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED								
		1				Moist, Brown [7.5YR 5/3], GRAVEL with Silt and Sand, GP-GM, non-plastic, very dense, sand medium to coarse grained.						Advanced in gravel 0-2.5'.
		2										
		3			2" SS 63				100			
		4										Advanced in gravels 4-5'.
		5				Wet, Brown [7.5YR 4/2], GRAVEL with Clay and Sand, GW-GC, no to low plasticity, very dense, gravels angular to rounded.						
		6			2" SS 67				65			
		7										Advanced 6.5-10'. Many boulders encountered while advancing.
		8										
		9				Moist, Reddish brown [5YR 4/3], GRAVEL with Silt, GP-GM, angular to subangular, no to low plasticity, very dense, gravels fractured.						
		10			2" SS 71				87			
		11										Advanced 11.5-15' through gravels.
		12										Cuttings indicate rounded gravels.
		13				Moist, Reddish brown [5YR 5/3], GRAVEL with Sand, GP, non-plastic, very dense, sand is very fine to medium grained.						
		14										
		15			2"SS 72				73			
		16										Advanced through boulders and dense gravel 16.5-20'.
		17										
		18										
		19										
		20			2" SS 60				100			
		21										



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DRILL HOLE LOG MILLTOWN DAM.GPJ, PIEDMONT.GDT 11/1/05

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		22					Moist, Dark reddish gray [5YR 4/2], GRAVEL with Sand, GP, angular to subrounded, non-plastic, very dense, gravels fractured from spoon. (Continued)						Advanced 21-25' through gravel with boulders.
		23											
		24											
		25											
		26	X			2" SS 61	Moist, Brown [7.5YR 5/2], GRAVEL with Clay and Sand, GP-GC, subrounded, low plasticity, dense, sands are fine to medium grained.			38			Advanced through boulders with gravel 26.5-30'.
		27											
		28											
		29											
		30	X			2" SS 55	Moist, Pinkish gray [7.5YR 6/2], GRAVEL with Silt and Sand, GP-GM, angular to subangular, non-plastic, very dense, gravels are fractured.			98			Advanced through large boulder 31-33'.
		31											
		32											
		33											
		34											
		35	X			2" SS 28	Moist, Brown [7.5YR 5/2], GRAVEL with Sand, GP, dense to very dense, many fractured gravels from spoon, sand is mostly fine to very fine grained.			41			Advanced in less dense gravels 36.5-40'.
		36											
		37											
		38											Water measured at 38' on 8/26/05 in piezometer A.
		39											
		40	X			2" SS 0	Very dense, no recovery.			100			Advanced 40.5-45' in gravels and boulders.
		41											
		42											
		43											
		44											



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES		SAMPLE ID	RECOVERY (%)	This log is part of a report prepared by Piedmont Engineering, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED									
				BULK			MATERIAL DESCRIPTION						
		45	X		2" SS	100	Saturated, Very dark grayish brown [10YR 3/2], CLAY with Silt, CL, low to medium plasticity, firm, organics present. (Continued)			8			45': drill bit is wet indicating water table. Driller feels water encountered at 44'. 45.5': Hand pen = 1.5 tsf 1.25 tsf 1.5 tsf A Shelby tube would have been pushed at 45' had we known we were in sediment. 48.5': torvane = 0.3 tsf; hand pen = 2.2 tsf 2.4 tsf 2.1 tsf
		46	X										
		47	X		Shelby	100	Saturated, Olive gray [5Y 4/2], SANDY SILT, ML, non-plastic, loose.		NP/NP				
		48	X										Start of drilling on 7/29/05.
		49	X		3" SS	100	Saturated, Very dark grayish brown [10YR 3/2], SILT with Clay, ML, low plasticity, firm, organics present, 3-4" cobble in bottom of spoon, @49.5', with very fine sand.			13			
		50	X		3" SS	100				4			
		51	X		2" SS	67	Saturated, Dark grayish brown [10YR 4/2], CLAYEY GRAVEL with Sand, GP-GC, subrounded, no to low plasticity, medium dense in first half of interval, very dense in second half of interval.			26			Advanced 51.5-55' in gravels and cobbles
		52	X										
		53	X										
		54	X										Advanced 55.2-60'. Slow advancing through gravels with cobbles and boulders.
		55	X		2" SS	0				100			
		56	X										
		57	X										Wet sample may be from water added to aid in augers advancing through very dense material.
		58	X										
		59	X										
		60	X		2" SS	61	Saturated, Brown [7.5YR 5/3], CLAYEY GRAVEL with Sand, GC, angular to subangular, no to low plasticity, medium dense in first half of interval, dense in second half of interval, gravels fractured from split spoon.			38			Advanced 61.5-65' in gravel and cobbles. Water measured at 61.7' on 8/26/05 in piezometer B.
		61	X										
		62	X										
		63	X										Pilot bit was dry at 65'.
		64	X										
		65	X										
		66	X		2" SS	61				54			Advancing much faster now (66.5-70').
		67	X										



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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES			RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
			DRIVE	UNDISTURBED	BULK								
		68					Saturated, Brown [7.5YR 5/3], CLAYEY GRAVEL with Sand, GC, angular to subangular, no to low plasticity, medium dense in first half of interval, dense in second half of interval, gravels fractured from split spoon. (Continued)						Driller thinks water table encountered at 67'.
		69											
		70					Saturated, Brown [7.5YR 5/2], GRAVEL with Clay and Sand, GP-GC, angular to subrounded, low to medium plasticity, very dense, gravels fractured from spoon.			66			Advanced 71.5-75' in dense gravels.
		71											
		72					Saturated, Light gray [2.5Y 7/1], GRAVEL with Sand, GP, subangular to subrounded, non-plastic, dense, gravels fractured from spoon.			46			75': while advancing the 3 key coupler on the drill head fractured. Needs to be welded. Water level = 45.5'. Fracture welded and start drilling again.
		73											
		74					Total Depth = 76.5'.						Stopped drilling at 76.5' with CH2MHill approval.
		75											
		76											
		77											
		78											
		79											
		80											
		81											
		82											
		83											
		84											
		85											
		86											
		87											
		88											
		89											
		90											



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